

LOAN DOCUMENT

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------|-----------|------|------------------------------------------|------|-------------------------------|-------------|--------------------------|---------------|--|--|--|--|--|----|--|---------------|--|--------------------|--|--------------|-----------------------------|-----|--|--|--|--|
| | | PHOTOGRAPH THIS SHEET | | ① | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DTIC ACCESSION NUMBER | | LEVEL | INVENTORY | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <i>Final Work Plan for a Remedial Action Plan...</i> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | DOCUMENT IDENTIFICATION <i>Dec 94</i> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | DISTRIBUTION STATEMENT A Approved for Public Release Distribution Unlimited | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | DISTRIBUTION STATEMENT | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"><tr><td colspan="2">ACCESSION BY</td></tr><tr><td>NTIS</td><td>GRAM <input checked="" type="checkbox"/></td></tr><tr><td>DTIC</td><td>TRAC <input type="checkbox"/></td></tr><tr><td>UNANNOUNCED</td><td><input type="checkbox"/></td></tr><tr><td colspan="2">JUSTIFICATION</td></tr><tr><td colspan="2"> </td></tr><tr><td colspan="2"> </td></tr><tr><td colspan="2">BY</td></tr><tr><td colspan="2">DISTRIBUTION/</td></tr><tr><td colspan="2">AVAILABILITY CODES</td></tr><tr><td>DISTRIBUTION</td><td>AVAILABILITY AND/OR SPECIAL</td></tr><tr><td>A-1</td><td></td></tr></table> | | ACCESSION BY | | NTIS | GRAM <input checked="" type="checkbox"/> | DTIC | TRAC <input type="checkbox"/> | UNANNOUNCED | <input type="checkbox"/> | JUSTIFICATION | | | | | | BY | | DISTRIBUTION/ | | AVAILABILITY CODES | | DISTRIBUTION | AVAILABILITY AND/OR SPECIAL | A-1 | | | | |
| ACCESSION BY | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| NTIS | GRAM <input checked="" type="checkbox"/> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DTIC | TRAC <input type="checkbox"/> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UNANNOUNCED | <input type="checkbox"/> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| JUSTIFICATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| BY | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DISTRIBUTION/ | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| AVAILABILITY CODES | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DISTRIBUTION | AVAILABILITY AND/OR SPECIAL | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DISTRIBUTION STAMP | | DATE ACCESSIONED | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | DATE RETURNED | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20010116 017 | | REGISTERED OR CERTIFIED NUMBER | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DATE RECEIVED IN DTIC | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

H
A
N
D
L
E

W
I
T
H

C
A
R
E

**Final Work Plan for a
Remedial Action Plan in Support
of the Risk-Based Approach to
Remediation at KC-135 Crash Site**



**Wurtsmith Air Force Base
Oscoda, Michigan**

Prepared For

**Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas**

and

**Wurtsmith Air Force Base
Oscoda, Michigan**

December 1994

PARSONS ENGINEERING SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

AQ MOI-04-0717

**DEFENSE TECHNICAL INFORMATION CENTER
REQUEST FOR SCIENTIFIC AND TECHNICAL REPORTS**Title AFCEE Collection**1. Report Availability** (Please check one box)

- ☒ This report is available. Complete sections 2a - 2f.
☐ This report is not available. Complete section 3.

**2a. Number of
Copies Forwarded**1 each**2b. Forwarding Date**July/2000**2c. Distribution Statement** (Please check ONE box)

DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly below. Technical documents MUST be assigned a distribution statement.

- ☒ DISTRIBUTION STATEMENT A: Approved for public release. Distribution is unlimited.
- ☐ DISTRIBUTION STATEMENT B: Distribution authorized to U.S. Government Agencies only.
- ☐ DISTRIBUTION STATEMENT C: Distribution authorized to U.S. Government Agencies and their contractors.
- ☐ DISTRIBUTION STATEMENT D: Distribution authorized to U.S. Department of Defense (DoD) and U.S. DoD contractors only.
- ☐ DISTRIBUTION STATEMENT E: Distribution authorized to U.S. Department of Defense (DoD) components only.
- ☐ DISTRIBUTION STATEMENT F: Further dissemination only as directed by the controlling DoD office indicated below or by higher authority.
- ☐ DISTRIBUTION STATEMENT X: Distribution authorized to U.S. Government agencies and private individuals or enterprises eligible to obtain export-controlled technical data in accordance with DoD Directive 5230.25, Withholding of Unclassified Technical Data from Public Disclosure, 6 Nov 84.

2d. Reason For the Above Distribution Statement (in accordance with DoD Directive 5230.24)**2e. Controlling Office**HQ AFCEE**2f. Date of Distribution Statement
Determination**15 Nov 2000**3. This report is NOT forwarded for the following reasons.** (Please check appropriate box)

- ☐ It was previously forwarded to DTIC on _____ (date) and the AD number is _____
- ☐ It will be published at a later date. Enter approximate date if known. _____
- ☐ In accordance with the provisions of DoD Directive 3200.12, the requested document is not supplied because: _____

Print or Type Name

Laura Peña

Signature

Laura Peña

Telephone

210-536-1431

(For DTIC Use Only)

AD Number

MOI-04-0717

**FINAL WORK PLAN FOR A REMEDIAL ACTION PLAN IN SUPPORT
OF THE RISK-BASED APPROACH TO
REMEDIATION AT KC-135 CRASH SITE**

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

and

**WURTSMITH AIR FORCE BASE
OSCODA, MICHIGAN**

December 1994

Prepared by:

**ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290**

TABLE OF CONTENTS

| | <u>Page</u> |
|-------------------------------------------------------------------------------|-------------|
| Section 1 - Introduction | 1-1 |
| 1.1 Goals and Objectives | 1-1 |
| 1.2 Scope of Work | 1-2 |
| 1.2.1 Determining Contaminant Distribution..... | 1-2 |
| 1.2.2 Estimating Potential Risks to Human Health and the Environment | 1-4 |
| 1.2.3 Developing and Appropriate Remedial Approach | 1-5 |
| 1.3 Work Plan Organization | 1-6 |
| Section 2 - Review of Available Site Data..... | 2-1 |
| 2.1 Site Background..... | 2-1 |
| 2.2 Physical Setting | 2-4 |
| 2.2.1 Site Topography and Surface Hydrology | 2-4 |
| 2.2.2 Site Geology and Hydrology..... | 2-4 |
| 2.3 Nature and Extent of Contamination..... | 2-7 |
| 2.3.1 Soil Gas Data | 2-7 |
| 2.3.2 Soil Data | 2-9 |
| 2.3.2 Ground Water Data | 2-9 |
| 2.3.4 Surface Water Data | 2-12 |
| 2.3.5 Frequency of Free Product..... | 2-12 |
| Section 3 - Identification of Site Models..... | 3-1 |
| 3.1 Conceptual Site Model | 3-1 |
| 3.1.1 Definitions..... | 3-1 |
| 3.1.2 Previous Risk Estimates | 3-4 |
| 3.1.3 Contaminants of Concern | 3-4 |
| 3.1.4 Potential Source Areas and Release Mechanisms | 3-8 |
| 3.1.5 Fate and Transport Processes | 3-8 |
| 3.1.6 Potential Human and Ecological Receptors | 3-8 |
| 3.1.7 Exposure Points and Exposure Routes | 3-8 |
| 3.1.8 Target Remediation Goals..... | 3-10 |
| 3.2 Intrinsic Remediation and Bioplume II Model..... | 3-11 |
| 3.2.1 Biodegradation of Soil Contamination..... | 3-12 |
| 3.2.2 Biodegradation of Dissolved-Phase | |

TABLE OF CONTENTS (Continued)

| | <u>Page</u> |
|-------------------------------------------------------------------------|-------------|
| Contamination | 3-12 |
| 3.3 Other Quantitative Fate and Transport Models..... | 3-14 |
| Section 4 - Proposed Site Characterization Activities..... | 4-1 |
| 4.1 General Data Needs | 4-1 |
| 4.2 Sampling Strategy | 4-5 |
| 4.2.1 Soil Sampling | 4-5 |
| 4.2.2 Ground Water Monitoring Well Construcion and Development | 4-13 |
| 4.2.3 Ground Water Sampling..... | 4-14 |
| 4.2.4 Soil Gas Sampling..... | 4-16 |
| 4.2.5 Aquifer Testing | 4-16 |
| 4.2.6 Surface Water Sampling..... | 4-16 |
| 4.3 Source Removal Feasibility Testing | 4-16 |
| Section 5 - Remedial Option Evaluation and RAP Report | 5-1 |
| 5.1 RAP Objectives | 5-1 |
| 5.2 Major Components of the RAP..... | 5-2 |
| 5.2.1 Data Presentation..... | 5-2 |
| 5.2.2 Data Evaluation and Modeling | 5-4 |
| 5.2.3 Method of Risk Analysis | 5-4 |
| 5.2.3.1 Exposure Pathway Evaluation..... | 5-5 |
| 5.2.3.2 Identifying Cleanup Goals | 5-7 |
| 5.2.3.2.1 Air..... | 5-8 |
| 5.2.3.2.2 Soil | 5-8 |
| 5.2.3.2.3 Ground Water..... | 5-9 |
| 5.2.3.2.4 Surface Water..... | 5-10 |
| 5.2.3.3 Risk Determination | 5-10 |
| 5.2.3.4 Evaluation of Source Removal/ Risk Reduction Options | 5-10 |
| 5.2.3.4.1 Intrinsic Remediation Only With Long-Term Monitoring | 5-11 |
| 5.2.3.4.2 Limited Source Removal..... | 5-11 |
| 5.2.3.4.3 Intensive Source Removal and Ground Water Pumping | 5-12 |
| 5.2.4 Selection of a Recommended Approach..... | 5-12 |
| 5.2.5 Long-Term Monitoring Plan..... | 5-12 |
| 5.3 Regulatory Coordination Strategy | 5-13 |
| Section 6 - Proposed Project Schedule | 6-1 |

TABLE OF CONTENTS (Continued)

| | <u>Page</u> |
|-----------------------------------------------|-------------|
| Section 7 - References | 7-1 |
| Appendix A - Sampling and Analysis Plan | a-1 |
| Appendix B - Health and Safety Plan | b-1 |

TABLES

| <u>No.</u> | <u>Title</u> | <u>Page</u> |
|------------|-------------------------------------------------------------------------------------------------------------------------------|-------------|
| 2.1 | Analytical Results for Ground Water Sampling Performed in October and November 1992..... | 2-10 |
| 3.1 | Summary of Fuel/Water Partitioning Coefficients and Availability of Toxicity Data for the Major Components of JP-4..... | 3-6 |
| 4.1 | Soil and Ground Water Analytical Protocol | 4-6 |
| 4.2 | Site-Specific Sampling Strategy | 4-15 |

FIGURES

| <u>No.</u> | <u>Title</u> | <u>Page</u> |
|------------|-------------------------------------------------------|-------------|
| 1.1 | Risk-Based Remediation Flow Chart | 1-3 |
| 2.1 | Regional Location of Wurtsmith AFB..... | 2-2 |
| 2.2 | Location of KC-135 Crash Site..... | 2-3 |
| 2.3 | Existing and Abandoned Well Locations..... | 2-5 |
| 2.4 | Hydrogeologic Cross Section A-A' | 2-6 |
| 2.5 | Ground Water Table | 2-8 |
| 2.6 | Extent of Ground Water Total BTEX Contamination | 2-11 |
| 3.1 | Conceptual Site Model..... | 3-2 |
| 4.1 | Proposed Soil Boring and Well Locations | 4-2 |
| 4.2 | Point of Compliance Monitoring Wells | 4-3 |
| 5.1 | Example RAP Report Outline | 5-3 |
| 5.2 | Risk Analysis Method..... | 5-6 |
| 6.1 | Risk-Based Demonstration Schedule..... | 6-2 |

SECTION 1

INTRODUCTION

This work plan was prepared by Engineering-Science, Inc. (ES) and describes the scope of work required for the collection and analysis of data to complete a remedial action plan (RAP) in support of a risk-based remediation decision for soil and ground water contaminated with fuel hydrocarbons at the KC-135 Crash Site, Wurtsmith Air Force Base (AFB), Oscoda, Michigan. This work plan is the equivalent of a treatability study test design (TSTD) for the field test of the risk-based approach to remediation at the KC-135 Crash Site. This innovative technology is sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, Texas, under contract F41624-93-C-8044, "Risk-Based Approach to Fuel Spill Remediation." This field test is a component of a multi-site initiative being sponsored by AFCEE to demonstrate how quantitative fate and transport calculations and risk information based on site-specific data can be integrated to quickly determine the type and magnitude of remedial action required at a site to minimize contaminant migration and receptor risks.

1.1 GOALS AND OBJECTIVES

The risk-based approach is designed to combine natural, or intrinsic, remediation with low-cost source removal technologies such as *in situ* bioventing to economically reduce risks posed by subsurface petroleum spills. There are three primary goals of this field test project. The first goal is to determine if remedial actions are necessary to minimize contaminant migration and potential receptor exposure to fuel-hydrocarbon-contaminated environmental media at the KC-135 Crash Site. The second goal is to implement any necessary and appropriate remedial technologies at the KC-135 Crash Site. It is possible that at some fuel-contaminated sites, intrinsic remediation alone will be sufficient to minimize or eliminate potential risks to human health and the environment. Implementation of the intrinsic remediation option under these circumstances would always require long-term monitoring to confirm the effectiveness of this remediation approach. At other sites, however, it may be necessary to supplement intrinsic remediation and long-term monitoring with some type of engineered solution, such as source removal, to minimize contaminant migration and receptor exposure. A combination of removal (e.g., free product recovery, bioventing), intrinsic remediation, and/or administrative commitments (e.g., long-term monitoring, land use restrictions) constitute a remedial alternative. The third goal is to collect data on how best to implement a risk-based remediation at a site, which will eventually be incorporated into a programmatic protocol document on the risk based approach. This protocol document will standardize site characterization, modeling, and interpretive procedures. Lessons learned and case studies developed as part of this field

test program will be factored into the protocol document to illustrate how best to complete a risk-based remediation of a site.

The specific objective of the work described herein is to develop a RAP that identifies and evaluates an appropriate remedial alternative for contaminated environmental media at the KC-135 Crash Site at Wurtsmith AFB, Michigan, that will be protective of human health and the environment. This RAP will contain all the information normally required in RAPs. This work plan and the RAP are intended to meet the technical, procedural, and documentation requirements of a Type C remediation as defined by the Michigan Department of Natural Resources, Environmental Response Division (MDNR ERD, 1994). Type C remedial actions are designed to remediate a site to levels appropriate for industrial uses. Land use restrictions can be included as part of the Type C remediation because unrestricted use of the site is generally not appropriate. This work plan describes the specific site characterization activities and data analyses which will be performed in support of the RAP and the risk-based approach to remediation for the KC-135 Crash Site.

1.2 SCOPE OF WORK

The major milestones of this field test project are as follow: (1) gather site-specific data on the nature and extent of contamination in the soil and ground water at the KC-135 Crash Site; (2) determine whether an unacceptable risk to human health or the environment currently exists or may occur in the foreseeable future using quantitative contaminant transport models and risk estimates; and, if required, (3) evaluate, recommend, design, construct, and operate an innovative remedial alternative that both reduces the source of contamination and minimizes or eliminates potential risks to human health and the environment due to exposure to the KC-135 Crash Site contamination. These major milestones are briefly described in this section and illustrated in Figure 1.1.

1.2.1 Determining Contaminant Distribution

It is the intent of the Air Force to demonstrate a risk-based approach to remediation for the KC-135 Crash Site that will satisfy Type C cleanup requirements as defined by the MDNR Operational Memorandum #14 (MDNR ERD, 1994). The requirements include specific information and reports which are commensurate with the type of risk reduction standard to be demonstrated, the degree of risk posed by the contaminated area, and the type of remedial action to be performed. Type C remediation assumes an industrial, recreational, and commercial exposure and includes the option of land use restrictions. Therefore, site characterization efforts required to demonstrate attainment will involve identifying the principal risks at the site which must be addressed by a combination of source removal, intrinsic remediation, and/or long-term monitoring.

Site characterization studies in support of the risk-based approach for the KC-135 Crash Site will consider two primary contaminant phases associated with subsurface JP-4 fuel hydrocarbon contamination at this site:

- Residual fuel in the vadose zone (unsaturated) soils; and
- Dissolved-phase fuel contaminants in the ground water.

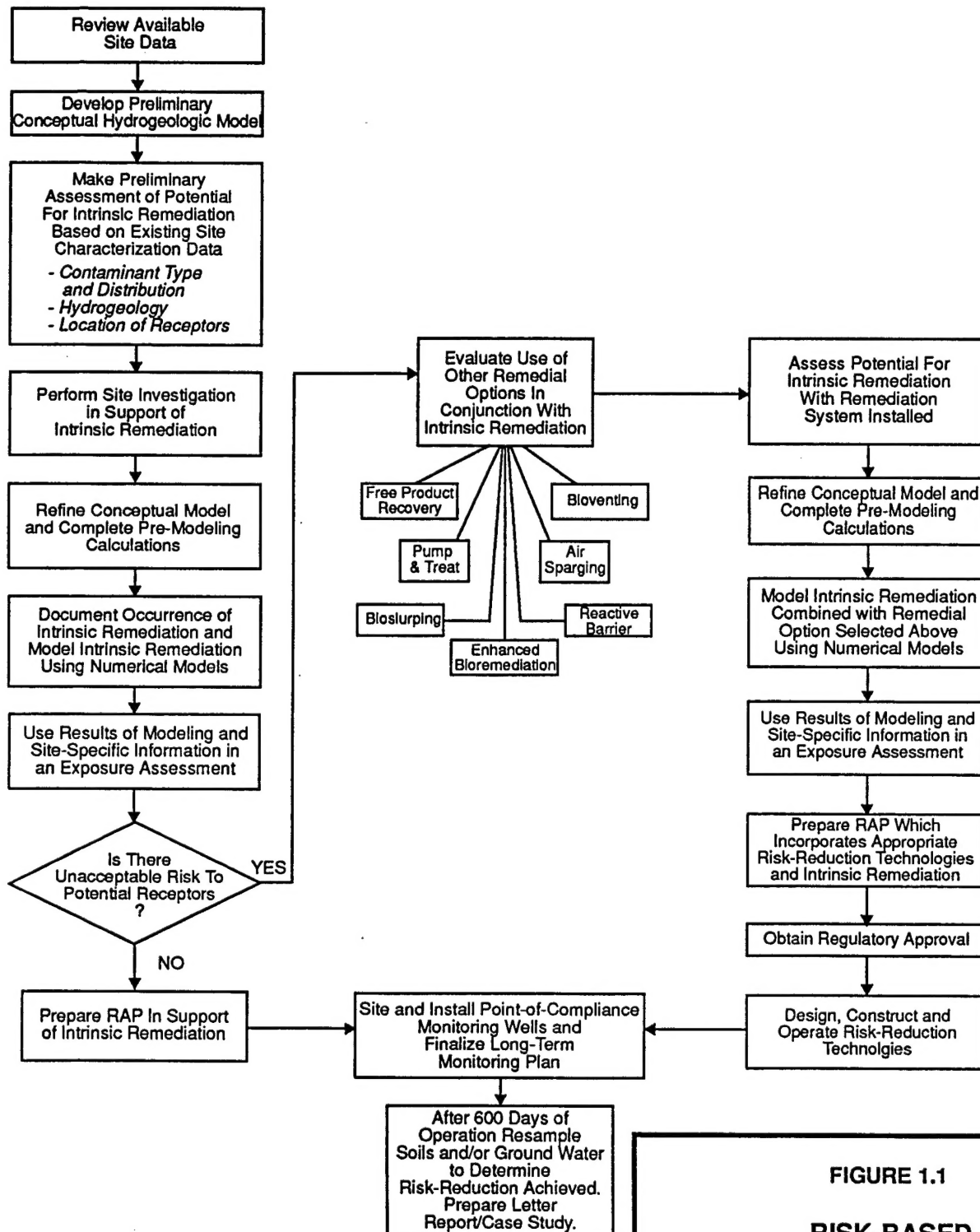


FIGURE 1.1
RISK-BASED
REMEDIATION FLOW CHART

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site Wurtsmith AFB, Michigan

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado

If present in sufficient quantities, fuel will spread downward and laterally through the vadose zone soils, leaving residual fuel in the vadose zone which can create a long-term ground water contaminant source (Abdul, 1988; American Petroleum Institute, 1980). Gradual partitioning of fuel contaminants from residual fuel product in vadose zone soil into ground water results in a dissolved-phase contaminant plume that can migrate downgradient under the influence of mass transport processes (e.g., Domenico and Schwartz, 1990). If contaminated ground water discharges into a surface water body, dissolved-phase hydrocarbons may also contaminate the surface water. Site characterization activities for the KC-135 Crash Site will include sampling of soil and ground water. Sufficient samples will be collected and analyzed to assess the risk to human health and the environment pursuant to Type C remediation. Section 4 of this work plan provides additional details on site characterization data needed to support a risk-based approach to remediation at the KC-135 Crash Site.

1.2.2 Estimating Potential Risks to Human Health and the Environment

The risk-based approach to remediation will provide a conservative estimate of the levels of residual fuel that can remain onsite and not pose an unacceptable risk to human health or the environment. This remediation approach allows site-specific flexibility in determining which potential remedial alternatives afford the highest degree of long-term effectiveness appropriate for the current and future uses of the site. Both the US Environmental Protection Agency (EPA) and the State of Michigan recognize that the mere presence of a contaminant does not necessarily warrant remediation, and that the goal of remediation investigations is to determine what remedial actions are necessary to eliminate or minimize risks to human health and the environment (EPA, 1987). Using site-specific data, a quantitative source-and-release analysis and an exposure pathway analysis will be completed to determine which if any of the contaminant phases (i.e., soil gas, contaminated vadose zone soils, and dissolved-phase contamination) may pose a risk to human health and the environment. Quantitative contaminant fate and transport models such as Bioplume II (Rifai et al., 1988) will be used to determine whether fuel contaminants could migrate to a potential receptor exposure point. This is one of the key steps in the risk-based approach to remediation because it ensures that costly engineered solutions are not employed at a site which does not and will not pose a risk to human health and the environment.

The risk-based approach to remediation is not intended to replace a traditional baseline risk assessment where the final decision is whether remedial actions are necessary (EPA, 1989b). However, a baseline risk assessment will not be necessary at sites to be addressed using the risk-based approach, as it has already been determined that some action will be taken. The risk-based approach is more analogous to an evaluation of the long-term risks associated with implementing a specific remedial action at a site (EPA, 1991b). This innovative approach streamlines the remedial decision process by focusing data collection and evaluation on identifying which remedial action most cost effectively reduces risks to human health and the environment. The risk-based approach compresses the traditional multistep remediation process into one project with the intent of quickly and cost effectively reducing any risks associated with chemical contamination at or migrating from the KC-135 Crash Site.

A quantitative, iterative process will be used to assess the potential effectiveness of various remedial alternatives (e.g., intrinsic remediation alone versus various source removal options coupled with intrinsic remediation) in minimizing contaminant migration and receptor exposure. Results of the comparison of onsite concentrations to Type B and Type C cleanup criteria (MDNR ERD, 1994) will be considered in selecting the appropriate remedial alternatives for the KC-135 Crash Site. Technical limitations, effectiveness, practicability, and other relevant features of the remedial alternatives will also be considered in selecting the preferred alternative. Sections 2 and 5 of this work plan provide more detail on how human health and environmental risks associated with various remedial alternatives will be evaluated as part of this field test.

1.2.3 Developing an Appropriate Remedial Approach

The risk-based approach to remediation is intended to quickly define a remedial alternative for a specific site that will reduce or eliminate significant risks to human health and/or the environment. Identification and evaluation of any remedial technology, including intrinsic remediation, will be based on an evaluation of (1) long-term effectiveness; (2) permanence; (3) ability to reduce contaminant toxicity, mobility, or volume; (4) implementability; and (5) cost. The RAP will provide sufficient technical data on the recommended remedial alternative to show that it eliminates or abates present and future threats to human health and the environment, and that appropriate control measures such as long-term monitoring are designed to supplement intrinsic remediation or any engineering controls.

A key objective of this evaluation will be to determine potential short- and long-term risks to the community and site workers. Determining how effective any one remedial technology may be at achieving desired protective remediation levels will require application of data from past treatability studies, an understanding of governing contaminant fate and transport processes, and engineering judgment. Both quantitative and qualitative analyses will be completed in support of the selection and design of an appropriate remedial action for the site. Long-term monitoring as part of this field test project will likely involve the installation and sampling of sentry and point-of-compliance wells. Sentry wells will be located immediately downgradient of the existing plume and will provide for early confirmation of engineering predictions. The point-of-compliance (POC) wells will be located further downgradient to verify that site-related contamination does not pose an unacceptable risk to potential receptors over time. The location of POC wells will be determined and additional wells installed (if necessary) after the initial field work has been completed and the rate of migration of the contaminant plume has been determined. Any requirements for land use controls or long-term monitoring required to protect human health and the environment will be clearly described in the RAP. Requirements for long-term monitoring and/or land use controls will be dependent upon the permanence or degree of long-term effectiveness afforded by the recommended remedial alternative. Current contractual guidelines call for an additional soil and/or ground water sampling event at 600 days of operation. The rates of contaminant removal associated with targeted source removal technologies and intrinsic remediation are relatively slow, and the 600 day interval between startup and resample should allow sufficient time for these technologies to initiate an appreciable reduction in contaminant concentration.

Evaluation of remedial technologies as part of this field test project will also focus on whether the technology can readily and economically achieve desired remediation levels and what uncertainties may be involved in this determination. Details on implementability with respect to expected time to achieve desired remediation levels will be factored into the evaluation.

The risk-based approach to remediation should streamline the remedial decision-making process by providing sufficient data to support the selection, design, and implementation of a low-cost final remedial alternative for the KC-135 Crash Site that will minimize contaminant migration and potential receptor exposure. The streamlined process should also reduce the amount of time between identification of a potential risk to human health and the environment and remediation of that risk. Additionally, site data to be collected will assist in subsequent risk analysis and remedial design efforts for other contaminated areas at Wurtsmith AFB by quantifying source release and transport mechanisms in local soils and ground water. This information will assist in the evaluation of the effectiveness of other remedial technologies.

1.3 WORK PLAN ORGANIZATION

This work plan is oriented toward the collection of site-specific data to be used to complete quantitative analyses of contaminant migration potential and the potential risks associated with contaminant migration. This work plan describes the need for additional data and how that data will be collected in the field and then analyzed using contaminant fate and transport models such as Bioplume II. Data from completed site investigations will be used to characterize the current nature and extent of potential source contamination at the KC-135 Crash Site. This work plan also describes the methods of risk analysis that will be used to identify and develop remedial actions for the KC-135 Crash Site. This work plan was prepared to coordinate the activities of all agencies involved in the RAP, including AFCEE, Wurtsmith AFB, the MDNR, and ES.

This work plan is based on a review of existing site characterization data and the data needs of the risk-based approach to remediation. The work plan consists of seven sections, including this introduction. Section 2 summarizes existing data on the physical characteristics and nature and extent of contamination at the KC-135 Crash Site. Section 3 presents a conceptual site model that will aid in defining necessary site characterization activities and subsequent data analyses. Section 4 describes the data needs of the risk-based approach to remediation for the KC-135 Crash Site. The proposed sampling strategy for the collection of additional site characterization data is also presented in Section 4. Section 5 discusses the proposed risk analysis methods and the RAP report format. Section 6 includes a proposed schedule defining milestone dates for the field test project at the KC-135 Crash Site. Section 7 contains the references used in preparing this document. This work plan also contains two appendices. Appendix A is the detailed site-specific sampling and analysis plan (SAP). Appendix B is the site-specific health and safety plan, an addendum to the program health and safety plan (ES, 1994).

SECTION 2

REVIEW OF AVAILABLE SITE DATA

Existing site-specific data were used to describe the physical characteristics of environmental media and the nature and extent of contamination at the KC-135 Crash Site. Review of available site data will aid in defining the additional site characterization data necessary to fill current data gaps, support quantitative modeling efforts, and evaluate, select, and implement the most cost-effective remedial alternative for the site.

2.1 SITE BACKGROUND

Wurtsmith AFB is located approximately 2 miles west of Oscoda, within Township 24 North, Range 9 East, Iosco County, Michigan (Figure 2.1). The KC-135 Crash Site is located in the western portion of the base, approximately 600 feet north of the Air Combat Command (ACC) instrument runway (Figure 2.2). Wurtsmith AFB is bounded on the east by the City of Oscoda and on the remaining sides by the Huron National and Au Sable State Forests.

The crash of the KC-135 aircraft occurred during an attempted landing in October of 1988. Approximately 3,000 gallons of JP-4 fuel were in the fuel tanks at the time of the crash. An unknown amount of fuel was consumed in the ensuing fire, and the remainder percolated into the ground. The US Geological Survey (USGS) conducted an initial site investigation during March 1989. The study included a soil gas survey and the installation of two ground water monitoring wells. The results of the soil gas survey indicated that JP-4 contamination in soil and ground water was confined to an elongated area surrounding the crash location (USGS, 1989).

The most recent site investigation was conducted by WW Engineering & Science (1993) under the supervision of the US Department of the Air Force. This investigation was conducted during the period from December 1992 through April 1993. Results of this investigation indicate that only ground water is contaminated with fuel hydrocarbons. A relatively narrow ground water plume of hydrocarbon compounds was found to extend from the crash site to a point approximately 600 feet downgradient. Field GC and laboratory analyses of soil samples indicate that soils are not contaminated with benzene, toluene, ethylbenzene, or total xylenes (BTEX) compounds or with polynuclear aromatic hydrocarbon (PAH) compounds. Only one soil sample contained a detectable concentration of a BTEX compound [xylene at 0.037 parts per million (ppm)]. No other organic compounds were detected in any other soil samples. Further details on the physical characteristics of the KC-135 Crash Site and

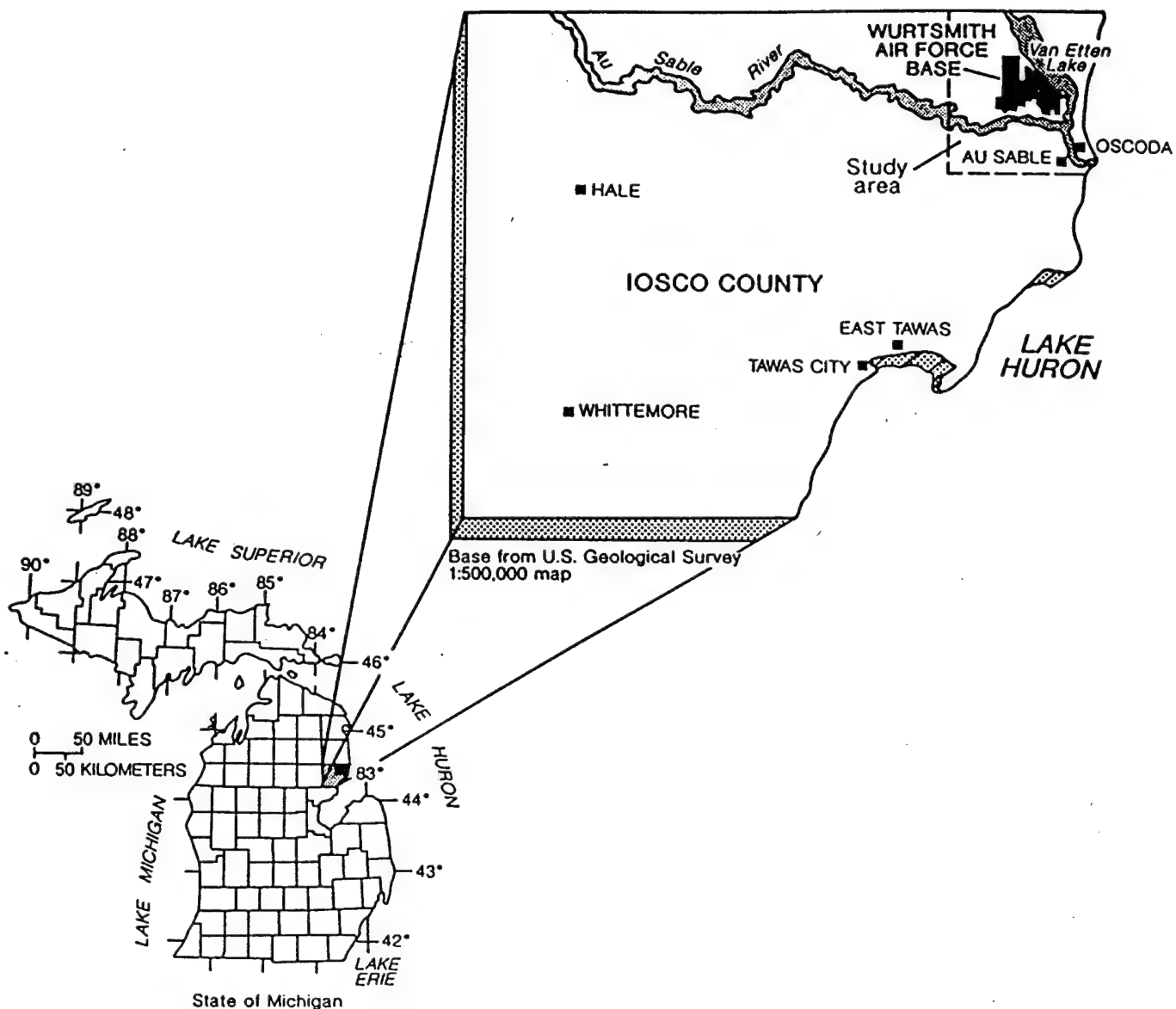


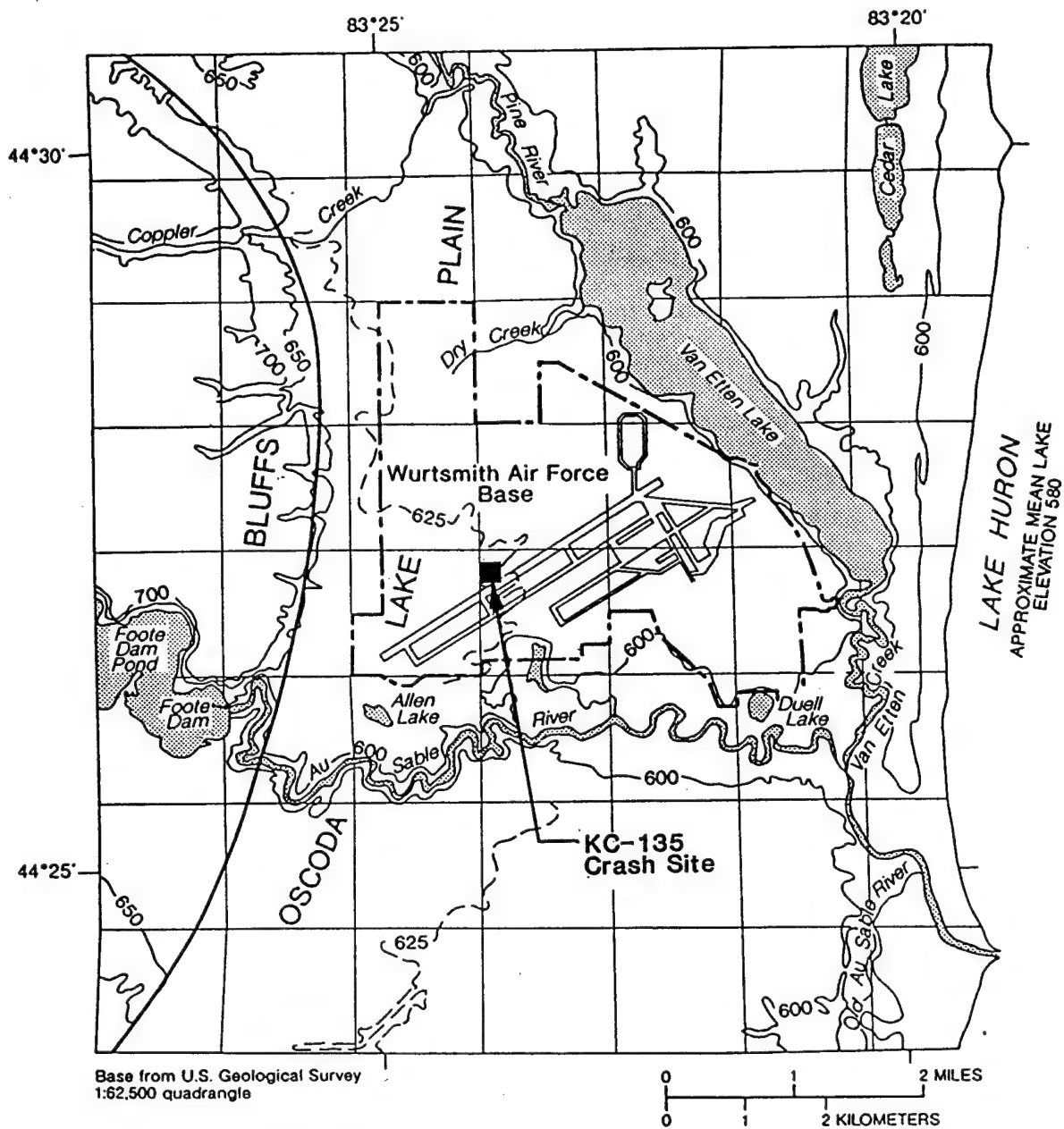
FIGURE 2.1

REGIONAL LOCATION OF WURTSMITH AFB

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado



EXPLANATION

- 650—TOPOGRAPHIC CONTOUR--Shows elevation of land surface. Contour interval 50 feet. Dashed line represents 625-foot contour. Datum is sea level
- BOUNDARY OF WURTSMITH AIR FORCE BASE
- BOUNDARY BETWEEN BLUFFS AND OSCODA LAKE PLAIN

FIGURE 2.2

LOCATION OF THE KC-135 CRASH SITE

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado

the probable nature and extent of subsurface fuel hydrocarbon contamination are presented in subsequent sections of this work plan.

2.2 Physical Setting

Data from previous site characterization efforts are reviewed, and relevant portions of these data are summarized in the following sections.

2.2.1 Site Topography and Surface Hydrology

Wurtsmith AFB and the surrounding area has relatively flat topography. The western portion of the base, including the KC-135 Crash Site, slopes very gently in an easterly direction. No abrupt elevation changes occur within the western area of the base except close to the Au Sable River, located south of the base. Figure 2.2 shows the location of the KC-135 Crash Site with respect to the entire Wurtsmith AFB and the surrounding environs.

The main surface water bodies in the vicinity of the KC-135 Crash Site are the Au Sable River, Allen Lake, and a small unnamed lake, all located south of the site. Both lakes drain into the Au Sable River. Much of the land between the Au Sable River and the southern boundary of the base is low lying and swampy.

Surface elevations range from between 625 and 630 feet above mean sea level (MSL) in the vicinity of the runway and the KC-135 Crash Site, to approximately 600 feet MSL on the swampy area adjacent to the Au Sable River. Surface drainage is primarily to the southeast, toward the Au Sable River. Surface runoff in the western portion of the base flows into one of two culverts and is discharged south of the base.

The surface of the site is a grassy area bounded on the north by the gravel perimeter road and on the south by the concrete runway. The Soil Conservation Service (SCS) has identified the Grayling sand as the primary soil association at the KC-135 Crash Site. The Grayling series consist of excessively drained soils formed in sandy glaciofluvial sediments with slopes between 0 and 6 percent.

2.2.2 Site Geology and Hydrogeology

The geology of Wurtsmith AFB consists of approximately 140 to 200 feet of unconsolidated deposits overlying the Mississippian-aged Marshall Formation sandstone and Coldwater Shale bedrock. Based on the boring log of well GST-3, drilled in the northern part of the base (Rama Rao & Alfred, 1992), the unconsolidated deposits beneath the base, progressing upward from the upper bedrock surface, consist of approximately 70 feet of glacial till, 40 feet of lacustrine silt and clay, and 70 feet of beach, eolian, and alluvial sand and gravel deposits.

Figure 2.3 depicts the existing and abandoned temporary well locations, and the location of the hydrogeologic cross section A-A' shown in Figure 2.4. Based on the information obtained during soil boring and well drilling (WW Engineering & Science, 1993), the site geology consists of approximately 2 feet of surficial topsoil underlain by

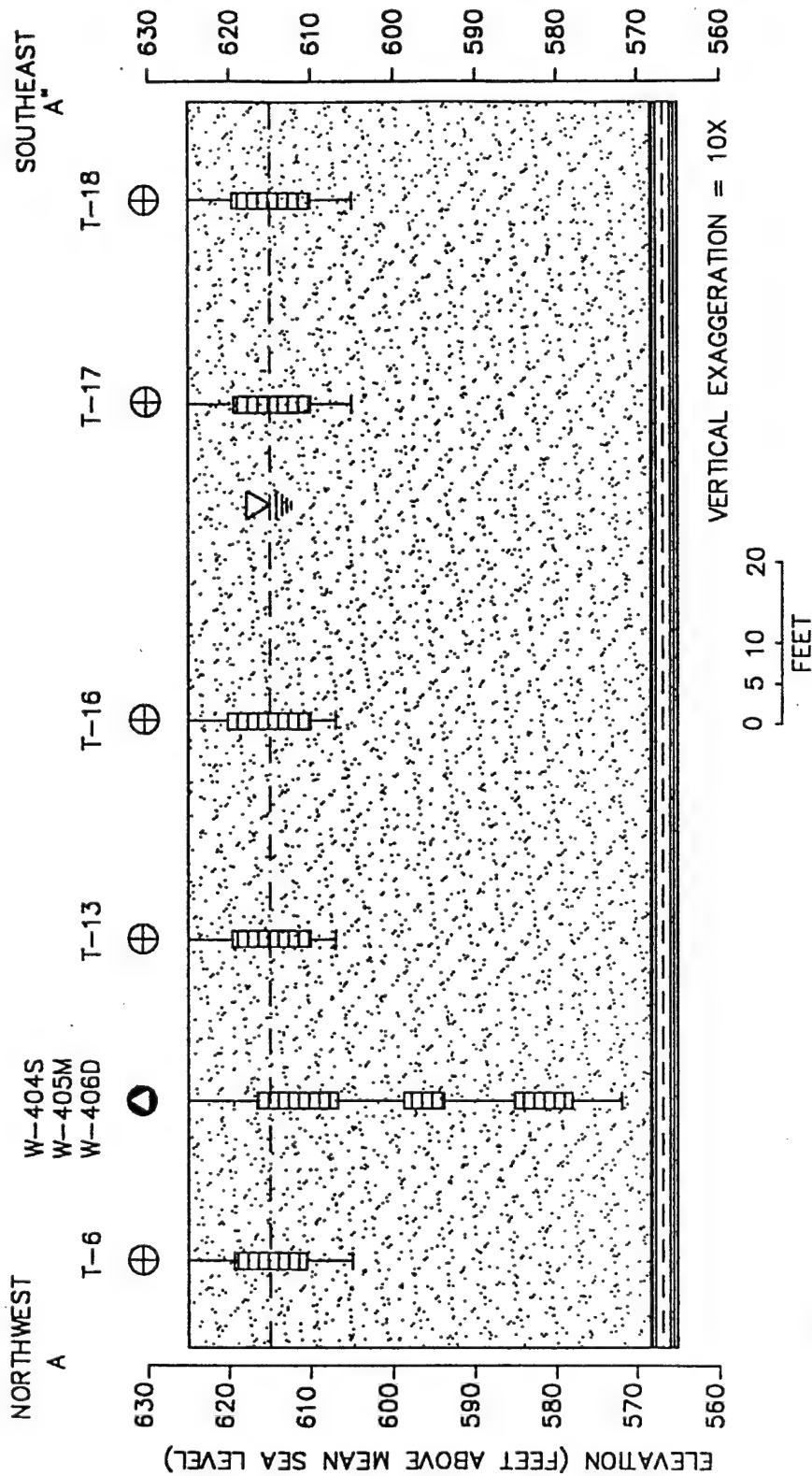


FIGURE 2.4
HYDROGEOLOGIC
CROSS SECTION A-A'

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site, Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado

at least 53 feet of fine- to coarse-grained sand. No soil boring at this site penetrated the entire thickness of the upper sand and gravel deposits. The sand unit contains occasional gravelly layers, generally between 3 and 8 feet below ground surface (bgs), and the sand tends to become finer grained below these layers. Sand below approximately 10 feet bgs is predominantly fine grained.

Ground water beneath Wurtsmith AFB and the KC-135 Crash Site occurs predominantly in two aquifers, the shallow sands and deeper glacial deposits, separated by the intervening lacustrine clay and silt layer. The clay and silt layer forms an aquitard between the two water-bearing zones and retards downward migration of contaminants. The shallow sand and gravel water table aquifer has an average saturated thickness of approximately 55 to 65 feet beneath Wurtsmith AFB and is the principal water supply source for the base. Ground water in the hydrogeologic units beneath the silty clay aquitard generally has high concentrations of dissolved solids or high chloride concentrations, making it undesirable as a drinking water supply for the base.

Figure 2.5 is a map of the approximate ground water surface at the KC-135 Crash Site, which was prepared from water levels in the permanent ground water monitoring wells measured on 9 January 1992 (WW Engineering & Science, 1993). The water table depth at the time of this investigation was between 6 and 10 feet bgs. Ground water flows in a southeasterly direction toward the Au Sable River with an average horizontal gradient of approximately 0.0025 foot per foot (ft/ft). The average vertical gradient is approximately 0.007 ft/ft downward. The ground water beneath the site will discharge into the Au Sable River, located approximately 1 mile southeast of the crash site (Figure 2.2), and ultimately into Lake Huron.

As determined from slug tests conducted as part of the remedial investigation (RI), the average hydraulic conductivity of the shallow aquifer is 68 feet per day (ft/day) in the upper portion and 71 ft/day deeper in the aquifer. The average linear velocity was calculated to be 0.58 ft/day, based on an average permeability of 69.1 ft/day, a gradient of 0.0025 ft/ft, and an assumed porosity of 0.30 (WW Engineering & Science, 1993).

2.3 Nature and Extent of Contamination

The following sections summarize existing analytical data on the nature and extent of contamination at or migrating from the KC-135 Crash Site. Data from the previous RI have been reviewed to estimate the probable nature and extent of contamination at the site.

2.3.1 Soil Gas Data

A 48-station soil gas survey for total hydrocarbons was conducted in 1989 by the USGS as part of the initial investigation of the crash site. The results of this soil gas survey indicated that soil and ground water had been contaminated in an elongate area

surrounding the crash site (USGS, 1989). This survey was conducted 5 months after the crash, while as much as 1.5 feet of free-phase product was floating on the ground water surface. However, as described in the next section, virtually no contaminants were detected in soil, so no additional soil gas data will be collected as part of this demonstration unless significant soil contamination is encountered in the proposed soil borings.

2.3.2 Soil Data

Soil samples for laboratory BTEX and PAH analyses were collected from the KC-135 Crash Site as part of the RI conducted in October and November of 1992. Two soil samples from each of the soil boreholes were submitted for laboratory analysis, except at borehole T-1, from which three samples were collected and analyzed. Drilling in the vadose (unsaturated) soil zone generally did not yield materials with visible contamination, and laboratory results indicate that the soils at the KC-135 Crash Site were not impacted by BTEX or PAH compounds (WW Engineering & Science, 1993).

Only one soil sample, from boring T-1 at a depth of 5 to 7 feet, collected during the RI contained a detectable concentration of a BTEX compound (xylene at 0.037 ppm) which was only slightly above the Type A soil criteria of 0.03 ppm, but below the Type B criteria of 6 ppm (MDNR ERD, 1994). Additional soil borings will be drilled and sampled to determine whether there is any remaining BTEX in soil. Section 4 of this work plan presents the sampling strategy to delineate the vertical and horizontal extent of soil contamination at the site.

2.3.3 Ground Water Data

Laboratory analytical results for ground water samples containing contaminants which were collected during the RI are presented in Table 2.1. These data indicate the probable nature and extent of ground water contamination directly attributable to the KC-135 Crash Site. The ground water analytical results in Table 2.1 are compared to Michigan Act 307 Types A, B, and C criteria (MDNR ERD, 1990 and 1994). The distribution of known BTEX ground water contamination at the KC-135 Crash Site is shown on Figure 2.6.

As shown in Figure 2.6, total BTEX compounds have migrated downgradient in a relatively narrow plume extending at least as far as monitoring well T-16, located approximately 500 feet from the crash site. However, no BTEX compounds were detected in the temporary monitoring well T-17, located approximately 900 feet downgradient of the crash site. The maximum concentration of total BTEX compounds [15,800 parts per billion (ppb)] was measured in a sample from well USGS-4 at the crash site.

The highest concentration of benzene in ground water was detected downgradient of the crash impact site in well T-13 (280 ppb). In the source area, benzene was detected in the ground water at only one location (Well USGS-7) at a concentration of 1.5 ppb. The distribution of benzene in the ground water suggests downgradient movement of a slug of contamination.

TABLE 2.1
ANALYTICAL RESULTS FOR GROUND WATER SAMPLING PERFORMED IN OCTOBER AND NOVEMBER 1992
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

| | Type A | | Type B | | Type C | | T-1 | T-10-OF | T-11 | T-12 | T-13 | T-16 | W-404S | USGS-7 | USGS-4 |
|-------------------------|--------|----------|--------|----------|--------|----------|-----|---------|------|------|------|------|--------|--------|--------|
| | GW | Criteria | GW | Criteria | GW | Criteria | | | | | | | | | |
| Parameter (ppb): | | | | | | | | | | | | | | | |
| Benzene | 1 | | 1 | | 12 | | <1 | 2.2 | <50 | <1 | 280 | 28 | <10 | 1.5 | <500 |
| Ethylbenzene | 1 | | 700 | | 2000 | | 15 | 60 | 180 | 53 | 56 | <1 | 130 | <1 | 2400 |
| Toluene | 1 | | 800 | | 4600 | | 2.9 | 1.9 | 790 | 53 | 640 | <1 | 420 | 3.1 | 3700 |
| Xylenes | 3 | | 300 | | 38000 | | 180 | 92 | 940 | 270 | 360 | <3 | 700 | 17 | 9700 |
| Naphthalene | 5 | | 30 | | 750 | | <5 | <5 | 20 | 5 | <5 | <5 | 21 | <5 | 120 |

Sources: MDNR ERD, 1990, 1994; WW Engineering & Science, 1993.

The distribution patterns of the other BTEX compounds in ground water are similar to that of total BTEX. The maximum concentrations of toluene (3,700 ppb), ethylbenzene (2,400 ppb), and xylenes (9,700 ppb) were measured in ground water samples collected near the crash site itself.

A comparison of the analytical results to the Type A and B ground water criteria (Table 2.1) shows that several monitoring wells (T-10, T-11, T-13, T-16, W-404S, USGS-7, and USGS-4) contained concentrations of BTEX compounds and naphthalene above their respective Type A and B cleanup criteria. This analysis was performed as part of the risk evaluation during the RI (WW Engineering & Science, 1993). For a more detailed discussion of the risk evaluation results, refer to Sections 3.0 and 5.0. The Type B ground water criteria presented in Table 2.1 for ethylbenzene (700 ppb), toluene (800 ppb), and xylene (300 ppb) are based on adverse aesthetic (taste or odor thresholds) while the criterion for benzene (1 ppb) is health-based. The health-based cleanup criteria for ethylbenzene, toluene and xylene are 700, 1,000, and 10,000 ppb, respectively (MDNR ERD, 1994). Only well USGS-4 had ethylbenzene, toluene, and xylene concentrations exceeding health-based Type B criteria. Compliance with Type B criteria is achieved when the concentration of a compound in ground water is below the lower of the health-based or aesthetic-based cleanup criteria (MDNR ERD, 1994).

The maximum concentration of naphthalene (120 ppb) was detected at well USGS-4. This concentration was the only detection above the Type B criterion. Naphthalene was also detected above the Type A criterion in two additional wells (Table 2.1).

Because previous site investigations did not collect ground water data necessary to model contaminant transport and natural attenuation, additional well installation and ground water sampling is necessary. Sufficient additional data will be collected to support the risk-based approach to remediation at the KC-135 Crash Site. Section 4 summarizes the necessary additional hydrogeologic characterization at the KC-135 crash site that will be completed as part of this project.

2.3.4 Surface Water Data

Surface water data were not collected as part of the RI conducted by WW Engineering & Science in 1992 and 1993. The ground water BTEX plume has migrated about 500 feet from the crash impact site, and the nearest ground water discharge points, the unnamed pond and the Au Sable River, are located at least 3,000 feet downgradient of the site. Therefore, the KC-135 Crash Site is not a suspected source of surface water contamination.

2.3.5 Frequency of Free Product

Free product was measured in monitoring wells USGS-4 and USGS-7 between April 1989 and early November 1991. The maximum thickness was 1.58 feet and 1.28 feet measured in wells USGS-4 and USGS-7 in 1989, respectively. However, no free product was detected in either well by 22 November 1991. During the most recent investigation, conducted during December 1992 through April 1993 (WW Engineering & Science, 1993), no free product was detected in either of these or any other wells or soil borings.

Although free product is not anticipated to be encountered during the field work phase of this project, if free product is detected and can be collected, a sample will be collected and analyzed for its total BTEX content to determine how any remaining free product is partitioning into the underlying ground water and contributing to the dissolved-phase BTEX plume at the KC-135 Crash Site.

SECTION 3

IDENTIFICATION OF SITE MODELS

It will be necessary to collect sufficient data to comparatively evaluate the long-term effectiveness of various remedial alternatives at eliminating or minimizing current or potential future risks to human health and the environment. Section 3.1 describes a conceptual site model for the KC-135 Crash Site, which includes possible source and release mechanisms, governing fate and transport processes, potential exposure points and routes, and potential human and environmental receptors. Section 3.2 describes the Bioplume II model which will be used to quantitatively evaluate whether dissolved-phase ground water contamination can migrate to a receptor exposure point. Section 3.3 describes other quantitative contaminant fate and transport models that may be used to evaluate exposure potential from contamination in environmental media other than ground water.

3.1 CONCEPTUAL SITE MODEL

The purpose of developing a conceptual site model (CSM) is to evaluate existing information about the physical characteristics of the site, including potential contaminant sources, chemicals of concern, release mechanisms (e.g., leaching and volatilization), governing fate and transport processes (e.g., molecular diffusion, ground water migration), potential human and ecological receptors (e.g., current on-base workers, potential future on-base residents, current/future off-base residents, terrestrial wildlife), exposure points (i.e., locations where receptors could come into contact with site-related contamination), and routes of exposure (e.g., inhalation, incidental ingestion, dermal contact), to identify the types of data necessary to quantify receptor exposure. The CSM will be used to define the nature of additional site characterization activities required at the KC-135 Crash Site to support identification, selection, and implementation of a final remedial alternative that minimizes contaminant migration and receptor exposure. The CSM constructed for the KC-135 Crash Site is shown schematically in Figure 3.1.

3.1.1 Definitions

It is appropriate at this point to define some of the key terms used in the risk-based approach to remediation at the KC-135 Crash Site. A *risk assessment* is the quantitative estimation of a hazard. A *baseline risk assessment* estimates the hazards that might exist if no remediation or institutional controls are applied at a site. A *risk analysis* is analogous to a baseline risk assessment under CERCLA in that the risks to human health and the environment are assessed. The key difference between a risk

assessment and a risk analysis is in the guidance on which they are based. A risk assessment involves the calculation of probabilities of risk while a risk analysis compares the appropriate cleanup criteria (defined by the State of Michigan for Wurtsmith AFB) to representative onsite contaminant concentrations.

A CSM qualitatively identifies how potential human and ecological receptors could come into contact with site-related contamination. A CSM is then used to assess data needs and guide data collection and analysis efforts. An *exposure assessment* involves estimating the type and magnitude of receptor exposures to contaminants of concern (COCs) that are present at or migrating from a site. COCs are chemicals that are potentially site-related and the data for which are of sufficient quality for use in a quantitative risk assessment. A *risk assessment concentration* or *exposure-point concentration* is the highest concentration a potential receptor would reasonably be expected to contact. The risk-based approach to remediation uses conservative quantitative models that account for the effects of fate and transport processes to estimate exposure-point concentrations. The probable effectiveness of intrinsic remediation and other innovative source removal technologies such as bioventing to reduce exposure-point concentrations will be determined using conservative quantitative models.

Chemical-specific remediation goals define the "acceptable" concentration of chemicals that can remain onsite following remediation and still meet remedial action objectives. These cleanup goals can either be risk-based or based on promulgated criteria. Remediation goals will be used to identify, select, and design an appropriate remedial alternative that will minimize or eliminate risks due to exposure to site-related contaminants. Remediation goals will be developed using the procedures outlined in Operational Memorandum #14 (MDNR ERD, 1994). *Type A remedial action requirements* establish the analytical method detection limit and/or background levels as the cleanup criteria. The requirements also define the points of compliance as every point within a site and include no post-closure requirements or responsibilities. *Type B remedial action requirements* establish risk-based cleanup criteria based on a residential exposure scenario. Type B requirements also define the points of compliance as every point within the site and include no post-closure requirements or responsibilities. *Type C remedial action requirements* are designed to evaluate risks from contaminants at industrial sites. The cleanup criteria are risk-based, but generally assume an industrial exposure. Type C criteria can also be adjusted to reflect site-specific conditions. Type C requirements define the point of compliance as the point of exposure to human or environmental receptors. Type C remediations include more post-closure requirements and responsibilities than either Type A or B remediations.

The risk evaluation to be performed on the data from the KC-135 Crash Site will comply with the State of Michigan requirements for Type C remedial action plans (as presented in Operational Memorandum #14). A three-tiered approach to site cleanup (Type A, B, or C) was developed by the State of Michigan as part of Act 307 for determining appropriate remedial actions to take at contaminated sites. The State of Michigan regulations are assumed to have primacy over EPA regulations in the remediation of the KC-135 Crash Site. The risk analysis will involve comparing the cleanup criteria presented in Operational Memorandum #14 to the exposure-point concentrations developed using the quantitative fate and transport models to estimate

the type and magnitude of remedial alternative required to protect human health and the environment. More details on the proposed risk analysis methods are presented in Section 5 of this work plan.

A *risk analysis* is analogous to a baseline risk assessment under CERCLA in that the risks to human health and the environment are assessed. The key difference between a risk assessment and a risk analysis is in the procedural guidance on which they are based. A risk assessment involves the calculation of probabilities of risk, while a risk analysis compares the appropriate cleanup criteria (defined by the State of Michigan for Wurtsmith AFB) to representative onsite contaminant concentrations.

3.1.2 Previous Risk Estimates

A risk evaluation was performed for the KC-135 Crash Site as part of the RI (WW Engineering & Science, 1993). The risk evaluation complied with the procedures and requirements established by the State of Michigan. The risk evaluation compared measured onsite concentrations to both Type A and Type B cleanup criteria.

In soil, no compounds were present in concentrations greater than their respective Type A and Type B criteria. In fact, only one chemical (xylene) was detected in one soil sample. In ground water, however, naphthalene, benzene, ethylbenzene, xylene, and toluene were detected at concentrations exceeding their respective Type A and Type B cleanup criteria. Based on the risk evaluation, it was concluded that the soil at the crash site is not impacted by either BTEX or PAH compounds, and no further remedial action for soil is warranted. Ground water quality under the crash site has been impacted by fuel constituents. The highest concentrations of contaminants are found in the plume of contamination extending approximately 500 feet downgradient from the point of the crash. The risk analysis recommended that a Type C closure be pursued for the ground water at the KC-135 Crash Site. The Type C closure should include deed restrictions on ground water use to prohibit onsite use and a long-term monitoring program to ensure that onsite ground water contaminants do not migrate beyond the property boundary or near the base water supply wells. The risk analysis methods proposed as part of this field test are consistent with and build upon previously recommended remediation strategies. In addition, continued use of the streamlined risk analysis approach developed by the State of Michigan should facilitate success in implementing remediation of ground water contamination at the KC-135 Crash Site.

3.1.3 Contaminants of Concern

This risk-based field test project will address the specific chemical constituents that may drive potential risks and impact the final remedial design for the KC-135 Crash Site. The COCs for the KC-135 Crash Site depend on the nature of the source (i.e., JP-4 jet fuel); the affected media (i.e., soil gas, soil, and ground water); the fate, transport, toxicity, and regulatory status of various JP-4 jet fuel constituents; as well as historical data for the KC-135 Crash Site. Details on the chemical composition of JP-4 jet fuel, the physiochemical properties of these constituents, and their toxicities are important factors that may influence the desired remediation goals for the site.

The major component categories (and their represented percentages by weight) in JP-4 are n-alkanes (32 percent), branched alkanes (31 percent), cycloalkanes (16 percent), benzenes and alkylbenzenes (18 percent), and naphthalenes (3 percent). Other nonhydrocarbons are not important components in JP-4 by weight.

The environmental behavior of each group of specific hydrocarbons must be considered when identifying COCs for the KC-135 Crash Site. For example, some compounds may be relatively mobile and nonpersistent in soil. These compounds may leach effectively from contaminated soil into underlying ground water and migrate as a dissolved-phase plume. Conversely, other compounds may be immobile under unsaturated conditions and may therefore not contribute to ground water contamination. Thus, based on the physiochemical properties of each JP-4 constituent, the relative concentration of each will vary with time and distance from the source of contamination. This effect is commonly called weathering.

Partitioning of chemical constituents from free-phase and residual contamination is an important mechanism of weathering that should be evaluated when identifying those compounds most likely to pose a risk to potential receptors and to require remediation. In general, migration of JP-4 through soils may be retarded to some extent. Once the JP-4 reaches ground water, however, the water solubility of each chemical constituent governs how it partitions into ground water. A fuel/water partitioning coefficient (K_{FW}) can be used to estimate the maximum concentration in ground water as a result of free-phase JP-4 contamination. Available K_{FW} data support the observation that light aromatics such as the BTEX compounds represent the greatest fraction of JP-4 that could impact ground water quality (see Table 3.1). Therefore, these compounds may be transported and dissolved in ground water. Because JP-4 is composed of C_{14} and lighter hydrocarbons, it is likely to be significantly weathered where encountered at this site. Naphthalene is the only PAH detected at the site.

When establishing potential COCs for a site, it is also important to consider the availability and magnitude of toxicity values for each of the JP-4 constituents. Table 3.1 lists those compounds typical of JP-4 samples for which accepted human health toxicity values are available [e.g., from the Integrated Risk Information System (IRIS)]. No toxicity data or promulgated standards are available for most of the specific chemical compounds that could be present in JP-4. Toxicity values are available for the BTEX compounds and naphthalene.

Therefore, the COCs for soil and ground water at or migrating from the KC-135 Crash Site which will be addressed as part of this field test project include the BTEX compounds and naphthalene. Any free-phase fuel product samples collected during the field work phase of this project will be screened for naphthalene. This approach is consistent with State of Michigan guidance on remediating soil and ground water contaminated with volatile compounds (MDNR ERD, 1994).

TABLE 3.1
SUMMARY OF FUEL/WATER PARTITIONING COEFFICIENTS
AND AVAILABILITY OF TOXICITY DATA
FOR THE MAJOR COMPONENTS OF JP-4
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

| Fuel Component | % by Weight | Fuel/Water Partition Coefficient | Available Tox. Data? |
|-----------------------------|-------------|----------------------------------------|-------------------------|
| Benzene | 0.5 | 231 | YES |
| Toluene | 1.33 | 895 | YES |
| Ethylbenzene | 0.37 | 3410 | YES |
| o-xylene | 1.01 | 3160 | YES |
| m-xylene | 0.96 | 3530 | YES |
| p-xylene | 0.35 | 2960 | YES |
| Napthalene | 0.5 | 24000 | YES |
| 1,1,3-trimethylcyclohexane | 0.48 | 651000 | NO |
| 1,2,3,4-tetramethylbenzene | 0.75 | 45800 | NO |
| 1,2,3-trimethylcyclopentane | 0.25 | 276000 | NO |
| 1,2,4-trimethylbenzene | 1.01 | 12270 | NO |
| 1,2,4-trimethylcyclopentane | 0.25 | 276000 | NO |
| 1,2-dimethyl-4-ethylbenzene | 0.77 | 45800 | NO |
| 1,3,5-trimethylbenzene | 0.42 | 6490 | NO |
| 1,3,5-trimethylcyclohexane | 0.99 | 651000 | NO |
| 1,3-diethylbenzene | 0.46 | 45800 | YES |
| 1,3-dimethyl-5-ethylbenzene | 0.61 | 45800 | NO |
| 1,4-dimethyl-2-ethylbenzene | 0.7 | 45820 | NO |
| 1-methylnapthalene | 0.78 | 27000 | NO |
| 1-methyl-2-ethylbenzene | 0.23 | 7710 | NO |
| 1-methyl-2-ethylcyclohexane | 0.39 | 9360 | NO |
| 1-methyl-2-isopropylbenzene | 0.29 | 35100 | NO |
| 1-methyl-3-ethylbenzene | 0.49 | 12200 | NO |
| 1-methyl-3-ethylcyclohexane | 0.17 | 9366 | NO |
| 1-methyl-4-ethylbenzene | 0.43 | 6690 | NO |
| 1-methyl-4-ethylcyclohexane | 0.48 | 9360 | NO |
| 1-methyl-4-propylbenzene | 0.4 | 45800 | NO |
| 2,2,3,3-tetramethylbutane | 0.24 | 509000 ✓ | NO |
| 2,2-dimethylbutane | 0.1 | 37800 | NO |
| 2,2-dimethylhexane | 0.71 | 509000 | NO |
| 2,2-dimethylpentane | 0.25 | 37000 | NO |
| 2,4-dimethylhexane | 0.58 | 509000 | NO |
| 2,5-dimethylheptane | 0.52 | 1860000 | NO |
| 2,5-dimethylhexane | 0.37 | 509000 | NO |
| 2,6-dimethylnapthalene | 0.25 | 593000 | NO |
| 2,6-dimethylundecane | 0.71 | 333000000 | NO |
| 2-methylheptane | 2.7 | 1330000 | NO |
| 2-methylhexane | 2.35 | 430000 | NO |

TABLE 3.1 (Continued)
SUMMARY OF FUEL/WATER PARTITIONING COEFFICIENTS
AND AVAILABILITY OF TOXICITY DATA
FOR THE MAJOR COMPONENTS OF JP-4
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

| Fuel Component | % by Weight | Fuel/Water Partition Coefficient | Available Tox. Data? |
|--------------------------------|---------------------|----------------------------------------|-------------------------|
| 2-methylnaphthalene | 0.56 ^{PAH} | 31000 | NO |
| 2-methyloctane | 0.88 | 2460000 | NO |
| 2-methylpentane | 1.28 | 61900 | NO |
| 2-methylundecane | 0.64 | 127000000 | NO |
| 3,3-dimethylhexane | 0.26 | 509000 | NO |
| 3,4-dimethylheptane | 0.43 | 1860000 | NO |
| 3-methylheptane | 3.04 | 1650000 | NO |
| 3-methylhexane | 1.97 | 270000 | NO |
| 3-methyloctane | 0.79 | 2450000 | NO |
| 3-methylpentane | 0.89 | 66350 | NO |
| 4-ethylheptane | 0.18 | 2450000 | NO |
| 4-methylheptane | 0.92 | 647000 | NO |
| 4-methyloctane | 0.86 | 15100000 | NO |
| cis-1,2-dimethylcyclopentane | 0.34 | 16600 | NO |
| cis-1,3-dimethylcyclohexane | 0.42 | 160000 | NO |
| cis-1,3-dimethylcyclopentane | 0.54 | 16600 | NO |
| Cyclohexane | 1.24 | 11700 | NO |
| Dimethylcyclohexane | 0.43 | 160000 | NO |
| Ethylcyclopentane | 0.26 | 16600 | NO |
| Isobutane | 0.66 | 14300 | NO |
| Isopropylbenzene | 0.3 | 9040 | YES |
| Methylcyclohexane | 2.27 | 55300 | NO |
| Methylcyclopentane | 1.16 | 16600 | NO |
| n-butane | 0.12 | 11000 | NO |
| n-butylcyclohexane | 0.7 | 35200 | NO |
| n-decane | 2.32 | 644000000 | NO |
| n-dodecane | 2 | 786000000 | NO |
| n-heptane | 3.67 | 365000 | NO |
| n-hexane | 2.21 | 91000 | YES |
| n-nonane | 2.25 | 7160000 | NO |
| n-octane | 3.8 | 2020000 | NO |
| n-pentane | 1.06 | 18800 | NO |
| n-propylbenzene | 0.71 | 7090 | NO |
| n-tetradecane | 0.73 | 1.80E+09 | NO |
| n-tridecane | 1.52 | 488000000 | NO |
| n-undecane | 2.32 | 644000000 | NO |
| trans-2,3-dimethylcyclopentane | 0.36 | 16600 | NO |

3.1.4 Potential Source Areas and Release Mechanisms

Figure 3.1 presents a schematic of the CSM for the KC-135 Crash Site. It identifies the source, affected media, release mechanisms, migration routes, exposure routes, potential receptors, and assumptions as to whether or not the pathway is complete. The contaminant release mechanisms incorporated into the CSM shown in Figure 3.1 are as follow: (1) volatilization into the atmosphere; (2) partitioning from residual soil contamination or free product into ground water; and (3) groundwater discharge into surface water. The only pathways assumed to possibly be complete involve soil and ground water. Contaminants in air are assumed to be addressed through evaluation of risk posed by contaminants in soil (see Section 5). This approach is consistent with the nature of contamination suspected at the site, the physical characteristics of the surrounding area, and the other risk assessments completed for the base.

3.1.5 Fate and Transport Processes

Fate and transport processes included in the CSM for the KC-135 Crash Site include (1) molecular diffusion through unsaturated soil, (2) air dispersion, and (3) ground water migration. Ground water discharge into and transport in surface water is not considered a complete exposure pathway at the site because the ground water BTEX plume has migrated only about 500 feet, and the nearest ground water discharge points, the unnamed pond and the Au Sable River, are located at least 3,000 feet downgradient of the site. Plant uptake of contamination from soil and subsequent transport through food chain pathways is also not considered a significant fate process for volatile compounds. Because the BTEX compounds and naphthalene are not considered persistent in biota, there is limited risk to wildlife due to food chain dynamics. Further, there are no readily available data on the toxicity of these compounds to plants, suggesting that these compounds do not bioconcentrate or bioaccumulate. A more detailed description of how potential impacts to ecological receptors will be analyzed is included in the following section.

All but one of the COCs to be considered for the KC-135 Crash Site readily volatilize from water into air. The actual rate of emission from source soils at the site will be investigated as described in Section 4 of this work plan, and possibly modeled using the methods described in Sections 3.3 and 5. The COCs for the KC-135 Crash Site are also expected to partition from contaminated unsaturated soil, which may contain fuel residuals, into the underlying ground water and migrate downgradient as a dissolved-phase plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, adsorption), these dissolved-phase contaminants will be slowly removed from the ground water system by other naturally occurring destructive attenuation mechanisms, such as biodegradation, abiotic oxidation, and hydrolysis. The effects of these fate and transport processes on the dissolved-phase ground water plume will be investigated using a quantitative ground water and solute-transport model such as Bioplume II. Data collection and analysis requirements are discussed in Sections 4 and 5 of this work plan, respectively.

3.1.6 Potential Human and Ecological Receptors

In pursuing a Type C remediation, it is assumed that the KC-135 Crash Site meets the criteria for an industrial site as defined in Operational Memorandum #14 (MDNR ERD, 1994). By meeting the criteria for an industrial site, it will be established that the primary activity and land use at the site is industrial. The associated cleanup criteria reflect the fact that this type of exposure is less intense than the residential exposure, and land use restriction documentation is required as part of the Type C remediation.

As identified in the *Preliminary Final Environmental Impact Statement, Disposal and Reuse of Wurtsmith Air Force Base, Michigan* (Wurtsmith AFB, 1993), it is considered likely that reuse of the base will include continued use of the runway. Therefore the KC-135 Crash Site is expected to remain undisturbed except for potential remedial activities.

Current human receptors at the KC-135 Crash Site include only maintenance workers who may come in contact with contaminated soils while maintaining the runway. There are no domestic use wells identified downgradient from the Crash Site and the plume of contamination does not appear to be migrating vertically into other aquifers. Any downgradient ground water wells and their uses will be identified as part of the RAP. The nearest ground water/surface water interface (GSI) is approximately 3,000 feet from the site. The plume has only traveled about 500 feet from the crash site. Therefore, no potential receptors are expected to be exposed to contaminants in surface water. The exposure pathways to ground water are incomplete but will be retained in the risk evaluation as part of the Type C remediation as a conservative assumption and to be consistent with MDNR ERD (1994) guidance. The GSI values identified by the State of Michigan define the concentrations in ground water that will be protective of surface water in the event that such an exposure pathway is completed. Use of GSI values in comparison to future, offsite, modeled ground water concentrations is included in the risk evaluation method defined in Section 5 of this work plan.

Type C remediation does not include specific quantification of risks to ecological receptors because it is assumed that attainment of Type C requirements will be protective of these receptors. A qualitative evaluation of the presence of sensitive ecological receptors and specific chemical properties of COCs that could influence ecological exposure (e.g., bioaccumulation potential) will be completed to verify that no quantitative risk analysis is warranted. A separate analysis of risks to ecological receptors will not be included as part of the RAP for the KC-135 Crash Site, per Michigan guidance on Type C requirements (MDNR ERD, 1994).

3.1.7 Exposure Points and Exposure Routes

An exposure point is a location at which any potentially exposed receptor could come into contact with site-related contamination. On-base contaminated media will be considered possible exposure points only for those base personnel who currently have access to the KC-135 Crash Site and for potential future on-base personnel and residents who may contact contaminated ground water that migrates offsite. Potential

exposure points initially included in this CSM include the KC-135 Crash Site and the environs downgradient of the site that are likely to be affected by contamination at or migrating from the source area. Several of these potential exposure points may be eliminated from the final evaluation should fate and transport data demonstrate that site-related contamination could not reach these locations (i.e., the exposure pathway is incomplete).

Probable exposure routes are dependent upon which receptors come into contact with what contaminated media. Compliance with a Type C remediation requires evaluation of specific exposure routes involving soil and ground water for potential human receptors. Based on these requirements, the following exposure routes, considered viable for current and potential future human receptors, are incorporated into this CSM: (1) incidental ingestion of contaminated soil; (2) dermal contact with contaminated soil, and (3) ingestion of ground water. The first two exposure routes will be evaluated by comparing both current, onsite, measured concentrations and future, modeled onsite concentrations to Type C cleanup criteria. The last exposure route will be addressed by comparing future modeled ground water concentrations to Type B cleanup criteria. This approach is consistent with Operational Memorandum #14 (MDNR ERD, 1994) and is further described in Section 5.

As noted previously, a separate evaluation of risks to ecological receptors will not be completed as part of the RAP report for the KC-135 Crash Site. It is assumed that none of the ecological receptors present at the site represent a resource of special concern, and that compliance with a Type C remediation will be adequately protective of ecological receptors present at the site.

3.1.8 Target Remediation Goals

The risk analysis approach to be used to screen, evaluate, select, design, and implement the most cost-effective remedial alternative at a site is addressed in Section 5 of this work plan. The three types of cleanup criteria described in the State of Michigan regulations designed to implement Act 307, were used in an iterative method to determine which of the three types of cleanup criteria is most applicable to the KC-135 Crash Site as part of the RI (WW Engineering & Science, 1993). Onsite concentrations were first compared to Type A concentrations to determine if remediation is necessary at the site. If onsite concentrations exceeded Type A cleanup criteria, then onsite concentrations were compared to the site-specific Type B cleanup criteria. Finally, because onsite concentrations exceed Type B cleanup criteria, comparison to Type C cleanup criteria was recommended. Specifically, the recommendations of the RI include pursuing Type C cleanup criteria for the ground water at the site. Therefore, the risk-based remediation of KC-135 does not repeat this previous effort, but rather builds upon its findings by focusing on Type C cleanup criteria. Thus, chemical-specific cleanup goals will be defined by either Type B or C criteria, updated with the most current toxicity information. Type C cleanup criteria will be used as appropriate remediation levels for onsite soil and ground water concentrations. Type B cleanup criteria may be obtainable for onsite soils and ground water. If this is feasible, Type B cleanup criteria will be used as the appropriate remediation levels. Type B cleanup criteria will be used as appropriate remediation

levels. A more detailed discussion of the proposed risk analysis method is presented in Section 5.

3.2 Intrinsic Remediation and the Bioplume II Model

After KC-135 Crash Site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any exposure pathway for human or ecological receptors is complete. The Bioplume II model has proved useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. The Bioplume II model (Rifai et al., 1988) can be used to evaluate critical ground water fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Other quantitative models potentially suitable to simulate fate and transport in soil and air are presented in Section 3.3 of this work plan. Determining whether remedial alternatives that are protective of human health and the environment will be aided by quantitatively incorporating fate and transport processes into the evaluation. Quantitative fate and transport analyses can be used to determine what level and extent of remediation is required to meet defined remediation criteria.

An important consideration in determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment and what type of remedial alternative will be most cost effective in eliminating or abating these threats is an accurate estimate of the potential for natural biodegradation of BTEX compounds in the soil and ground water. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen, other electron acceptors such as nitrate and sulfate, and nutrients are available in the soil and ground water. The rate of natural biodegradation is generally limited by the lack of oxygen rather than by the lack of nutrients such as nitrogen or phosphorus.

Biodegradation of fuel hydrocarbons occurs when microorganisms catalyze the transfer of electrons from electron donors to electron acceptors during respiration. Electron donors can be organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons can be completely degraded or detoxified if they are used as the primary electron donor for microbial metabolism. Electron acceptors or elements or compounds that occur in relatively oxidized states and include oxygen, nitrate, sulfate, manganese, ferric iron, and carbon dioxide. Microorganisms preferentially use electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). Dissolved oxygen is used first as the prime electron acceptor. However, once the available oxygen is depleted and anaerobic conditions dominate in the subsurface, anaerobic microorganisms can use other electron acceptors in the following order of preference: nitrate, sulfate, manganese, ferric iron, and finally carbon dioxide.

The supply of oxygen to unsaturated soil is constantly renewed by vertical diffusion from the atmosphere. The supply of oxygen to a shallow, fuel-contaminated aquifer is constantly renewed by the influx of oxygenated, upgradient flow and the vertical diffusion of oxygen from the unsaturated soil zone into the ground water (Borden and Bedient, 1986). The rate of natural biodegradation in unsaturated soil and shallow

aquifers is largely dependent upon the rate at which oxygen enters the contaminated media.

3.2.1 Biodegradation of Soil Contamination

The rate of vertical diffusion of oxygen into unsaturated, contaminated soil is a function of both the air permeability of the soil and the concentration gradient between the ambient atmosphere and the soil. In general, downward natural diffusion processes are rate-limiting and do not substantially enhance potential natural biodegradation processes within unsaturated soils. Natural biodegradation is not expected to rapidly reduce soil contamination. It is possible, however, to optimize both of these conditions by introducing oxygen into the unsaturated soil via a low-rate air injection system. This innovative technology, called bioventing, supplies oxygen to soil bacteria employed in the biodegradation of fuel hydrocarbons. The radius of influence of each air injection point depends upon the operational parameters of the engineered bioventing system and the physical, chemical, and biological characteristics of the contaminated, unsaturated soil. The positive influences of oxygenating shallow unsaturated soil are considered an engineered source removal technology.

3.2.2 Biodegradation of Dissolved-Phase Contamination

Several well-documented and widely-accepted numerical models are available for modeling the fate and transport of fuel hydrocarbons under saturated conditions and accounting for the influences of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. The positive effect of these processes on reducing the actual mass of fuel-related contamination dissolved in ground water has been termed intrinsic remediation. In some cases, intrinsic remediation will reduce the dissolved-phase contaminant concentrations to below concentration levels warranting remedial action (i.e., Type A or B cleanup criteria), even if little or no source removal/reduction is implemented. In situations where intrinsic remediation will not reduce contaminant concentrations to below these levels, it may be possible to negotiate less stringent, site-specific final remediation goals that are still protective of human health and the environment given the type and magnitude of exposures most representative of current and potential future site conditions. For example, intrinsic remediation processes may reduce contaminant concentrations or prohibit significant migration over time such that the potential risks associated with exposure to site-related contamination are eliminated or reduced to an acceptable level.

The advantages of intrinsic remediation include: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive and allows continuing use of the land during remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the atmosphere during remediation activities; and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies. The main limitation of intrinsic remediation is that it is a long-term solution which requires regular monitoring to confirm its progress.

To estimate the impact of natural biodegradation on the fate and transport of BTEX compounds in ground water at a site, two important lines of evidence must be demonstrated (Wiedemeier et al., in progress). The first is a documented loss of contaminants at the field scale. Dissolved-phase concentrations of biologically-recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters such as ground water seepage velocity and dilution to demonstrate that a reduction in the total contaminant mass is occurring at the site. Trimethylbenzene will be used as a conservative tracer to estimate the effects of dilution on BTEX plume dissipation. The second line of evidence involves the use of chemical analytical data in mass balance calculations to show that a decrease in contaminant and electron acceptor (e.g., oxygen, nitrate, sulfate) concentrations can be correlated to increases in metabolic fuel degradation byproduct concentrations (e.g., carbon dioxide, methane, ferrous iron). With this site-specific information, the Bioplume II computer model can be used to simulate the transport of dissolved-phase BTEX compounds under the influence of electron-acceptor-limited biodegradation.

The Bioplume II model is based upon the USGS two-dimensional (2-D) solute transport model MOC, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. However, as part of this field test project, the biodegradation of fuel contamination will be activated by a superimposed plume of both oxygen and nitrate. Work completed as part of the natural attenuation (intrinsic remediation) field test program, also sponsored by AFCEE, suggests that these compounds are the primary electron acceptors at a fuel-contaminated site based on both thermodynamic and kinetic considerations. Use of both oxygen and nitrate in the Bioplume II model should provide a better estimate of the effectiveness of natural attenuation processes at the site in minimizing contaminant migration and reducing contaminant mass and toxicity. Use of both primary electron acceptors should also provide a better estimate of response time. Use of oxygen as the only electron acceptor can seriously underestimate the effects of natural degradation processes. Sulfate and reduced iron concentrations will not be included in the superimposed plume of electron acceptors, but this data will be collected for qualitative investigation of the total electron acceptor potential. The impact of including both oxygen and nitrate in the Bioplume II model for this site may be a reduction in the source removal activities and time required to achieve site-specific remediation goals.

Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the ground water and once for the electron acceptor plume. The two plumes are then combined using superposition at every particle move to simulate biological reactions between fuel products and the electron acceptors. Using even the most realistic worst-case data, Bioplume II generally predicts very limited migration of BTEX plumes due to natural attenuation processes. Bioplume II has been used to successfully demonstrate the effectiveness of intrinsic remediation at several sites (e.g., Wilson et al, 1986; Chiang et al., 1989; Rifai et al., 1988; Malone et al., 1993; Wiedemeier et al, 1993).

The risk-based approach to remediation is aimed at providing scientific evidence in support of the positive effects of intrinsic remediation and other innovative source removal technologies. The type and magnitude of these effects will be factored into the development of a final remedial alternative for the site. It is likely that intrinsic

remediation alone will be insufficient at many fuel hydrocarbon-contaminated sites to reduce or eliminate contaminant migration and receptor risks. Other innovative source removal technologies, such as bioventing, will be included in the fate and transport calculations, risk analysis, and remedial design as necessary to ensure that the final remedial alternative will protect current and future receptors from adverse exposures to any site-related contamination. The source removal technologies will be simulated in the intrinsic remediation modeling as a reduction in the source term used in the model. The need to use additional source removal technologies in conjunction with intrinsic remediation will be determined solely by the risk-based remediation goals. Section 5 provides more detail on how quantitative models such as Bioplume II will be used to assess how well various remedial technologies eliminate or reduce contaminant migration and receptor risks.

3.3 OTHER QUANTITATIVE FATE AND TRANSPORT MODELS

The Summers model can be used to evaluate the potential impact of contaminated soil on ground water quality via downward precipitation infiltration (EPA, 1989a). This model may be useful to determine the potential for cross-media contamination, which may act as a continuing source of ground water contamination. The Summers model assumes that a percentage of precipitation at the site will infiltrate and desorb contaminants from the soil based on equilibrium partitioning between soil and liquid phases. Application of a fuel/water partitioning model such as that developed by Bruce et al. (1991) may also be required to provide a conservative estimate of how free-phase JP-4 jet fuel dissolves into ground water.

Soil gas concentrations cannot be directly used to assess potential air impacts due to VOCs diffusing upward through the vadose zone into the atmosphere or accumulating in buildings if a more detailed assessment of inhalation risks is necessary. Inhalation risks will be assessed by evaluating COCs to determine if they are special concern materials, as described in Operation Memorandum #14 (MNDR ERD, 1994). If no special concern materials are identified, then MDNR guidance states that exposure control measures which are protective for other routes of exposure will be deemed protective for the inhalation pathway. If special concern materials are identified then a more detailed assessment of inhalation risks may be necessary.

Several air diffusion and dispersion models recommended by the EPA (1992c) are available to determine air concentration levels in the atmosphere at several exposure points and accumulating in buildings and will be used if a more detailed assessment of inhalation risks is necessary. If a more detailed assessment of inhalation risks is necessary, it may be appropriate to use a simple diffusion/intrusion model to estimate the average annual VOC concentration that could accumulate in buildings due to upward contaminant flux from soil and ground water and present a threat to individuals who may work or reside within buildings constructed on or adjacent to the KC-135 Crash Site.

SECTION 4

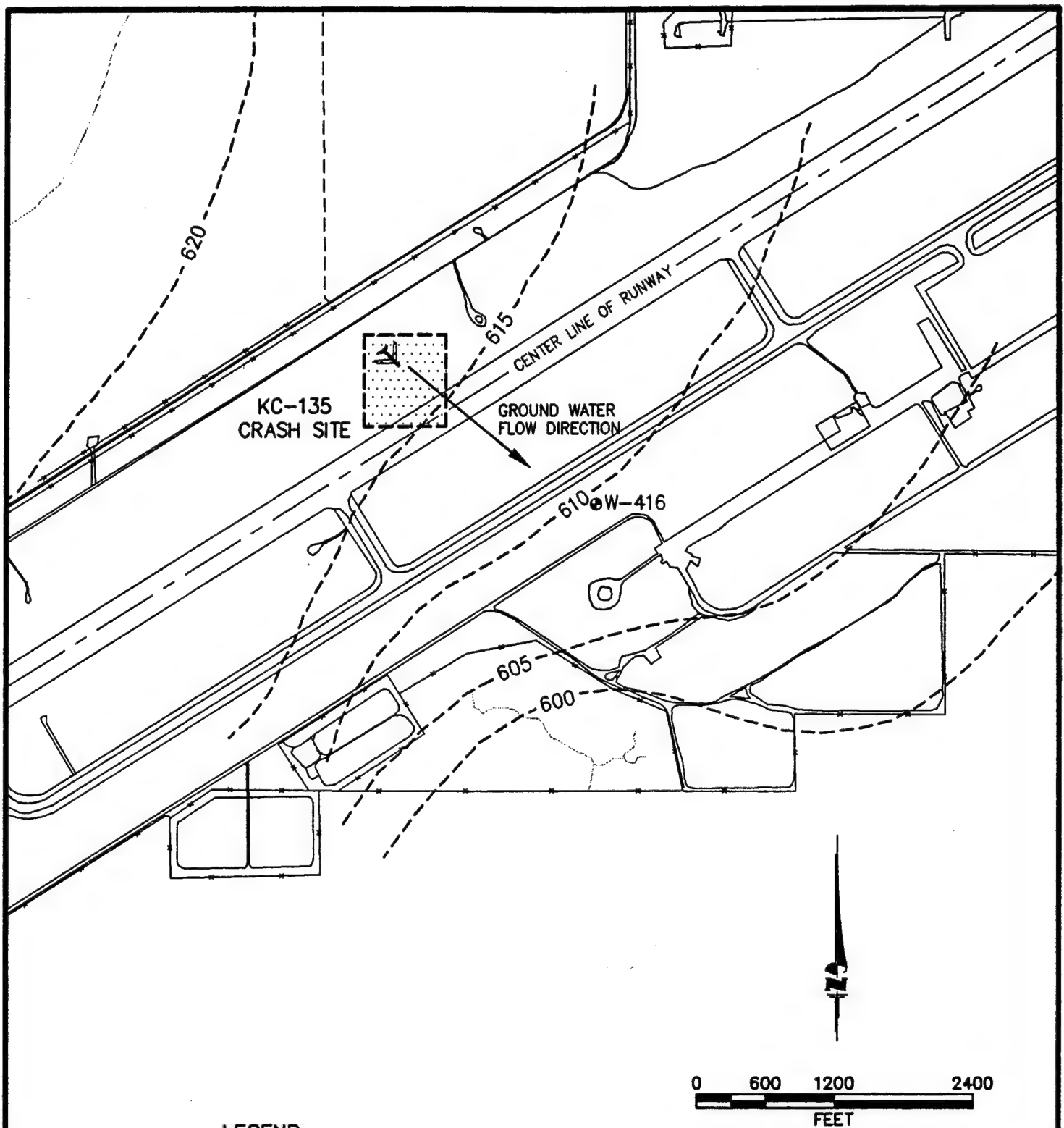
PROPOSED SITE CHARACTERIZATION ACTIVITIES

To facilitate development and implementation of a risk-based remedial action for the KC-135 Crash Site, additional site-specific environmental media data will be collected. Soil gas, soil, and ground water will be sampled to (1) delineate the nature and extent of contamination, (2) support fate and transport analyses, (3) develop appropriate exposure-point concentrations to compare to final remediation goals, and (4) evaluate and design an appropriate remedial alternative for the site. A sufficient number of samples from background and contaminated areas will be collected and analyzed for individual and indicator compounds to accurately evaluate the risks to human health and the environment posed by the site and to demonstrate the attainment of final cleanup levels.

Compound-specific analytical procedures will be used to determine the lateral and vertical extent and volume of contaminated media at the KC-135 Crash Site. Development of a risk-based remedial alternative for the KC-135 Crash Site will require an analysis of the potential chemical-specific threats posed to human health and the environment by individual compounds. Therefore, analytical data collected for the site will include a determination of the presence and concentration of individual chemicals.

4.1 GENERAL DATA NEEDS

Several data needs were identified as a result of developing the CSM for the KC-135 Crash Site and assessing the input requirements for the quantitative fate and transport models. These data are necessary to prepare a RAP in support of a risk-based remedial action for the KC-135 Crash Site. New ground water monitoring wells will be installed, and additional soil and ground water sampling will be performed. The new ground water monitoring wells were located for the specific purpose of supporting intrinsic remediation sampling and modeling. Wells have been located upgradient, within the plume, and downgradient in order to confirm the location of the BTEX plume and the distribution of electron acceptors. Wells will generally be screened over the upper 10 feet of the aquifer since the plume has not moved deeper based on the past multi-depth sampling at W404. Parsons ES intends to verify that vertical migration is not significant by constructing W404 as a nested well with screened intervals at 10-15 feet bgs, 30-35 feet bgs, and 50-55 feet bgs. Proposed well and soil borehole locations at the KC-135 Crash Site are shown on Figures 4.1 and 4.2. Figure 4.2 shows the proposed location of an additional down-gradient well (W-416), ground water surface



LEGEND

- 600--- GROUND WATER SURFACE ELEVATION
 (feet above mean sea level)
 W-416
 ● PROPOSED MONITORING WELL

FIGURE 4.2

POINT OF COMPLIANCE MONITORING WELLS

RAP Work Plan
 Risk-Based Approach to Remediation
 KC-135 Crash Site,
 Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado

contours, and the estimated ground water flow direction. Well W-416 will be used to evaluate downgradient hydrogeologic conditions and will also act as a model verification well. The location of POC wells will be determined, and additional wells installed (if necessary) after the initial field work has been completed and the rate of migration of the contaminant plume has been determined. Any additional existing information not incorporated into this work plan will also be reviewed and used to the extent practicable to evaluate and design an appropriate remedial alternative for the KC-135 Crash Site which eliminates or abates risks to human health and the environment. The data listed below will be collected during the field work phase of the risk-based approach to remediation.

Both vadose zone (unsaturated) and phreatic zone (saturated) soil characteristics to be determined include:

- Detailed stratigraphic analysis of subsurface media;
- Air-filled and/or effective porosity;
- Estimated moisture content (unsaturated only);
- Total organic carbon (TOC) content and pH;
- Total phosphorus and total Kjeldahl nitrogen (TKN) concentrations by depth;
- Concentrations of the total recoverable petroleum hydrocarbons (TRPH) and BTEX compounds; and
- Estimated vertical extent of free product smear zone (if present).

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the ground water surface;
- Location of potential ground water recharge and discharge areas; and
- Dispersivity (estimated).

Chemical hydrogeologic characteristics to be determined include:

- Determination of extent and thickness of free product, if any;
- Dissolved oxygen, sulfate, and nitrate/nitrite concentrations;
- Dissolved carbon dioxide, total alkalinity as carbonate and bicarbonate, methane and ferrous iron concentrations;
- Redox potential;

- Concentrations of each of the BTEX and PAH compounds;
- Temperature;
- Specific conductance;
- TOC content and pH; and
- Chemical analysis of free product, if any, to determine the mass fraction of BTEX and PAH compounds.

Table 4.1 lists the chemical analytical protocol for each of the environmental media to be sampled in support of a risk-based remedial design for the KC-135 Crash Site. This table also presents the detection limits required to support quantitative fate and transport analyses and calculation of exposure-point concentrations to compare to final remediation goals. Additional site-specific data necessary to support preparation of the RAP report include (1) general climatic data, including prevailing wind speed and direction, average precipitation (as snow and rain), and temperature range; (2) existing and proposed land use plans for portions of Wurtsmith AFB, including the KC-135 Crash Site and downgradient environs; (3) presence or suspected presence of sensitive subpopulations such as the base day-care center, threatened or endangered species, or special-concern habitats; (4) ground water well locations and use information for areas likely to be affected by ground water migration; and (5) additional site-specific data necessary to justify site-specific land use and exposure assumptions.

4.2 SAMPLING STRATEGY

Field investigation efforts will be completed in the following sequence: (1) drilling, soil sampling, and well installation in least contaminated areas; (2) drilling, soil sampling, and well installation in most contaminated areas; (3) well development; (4) collection of physical ground water data from least to most contaminated areas; and (5) collection of ground water samples from least to most contaminated areas for chemical analyses. Several of these activities can be conducted concurrently at the discretion of the PARSONS ES site manager to expedite the field work phase of this project. However, care must be taken to minimize cross-contamination and other medium-specific effects that could complicate data evaluation. Appendix A to this work plan is the detailed site-specific SAP. Specific procedures and protocols for each type of field activity to be completed at the KC-135 Crash Site, including quality assurance requirements, are presented in this appendix.

4.2.1 Soil Sampling

Soil drilling and sampling will be necessary to characterize the nature and extent of vadose and phreatic zone soil contamination at and immediately downgradient of the KC-135 Crash Site. Split-spoon soil samples will be collected from boreholes at 13 locations. Permanent bioventing wells or ground water monitoring wells will be installed at 12 of these soil boring locations (Figures 4.1 and 4.2), and the remaining soil boring will be abandoned. Soil cores will be carefully evaluated to determine the stratigraphy of the sample location and the vertical depth of any measurable or visible

TABLE 4.1
SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Soil

| Analysis | Method | Required | | Field or Laboratory | Analysis Classification* | Data Use |
|-----------------------------------|-------------------------|--------------------|--|------------------------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | Detection Limit | | | | |
| Total combustible hydrocarbons | Direct reading meter | low reading | | F | A | A field screening method to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination. |
| Benzene | GC Method SW8020 | 10 µg/kg | | L | B | Quantitative analysis to determine the nature and extent of soil contamination, the mass of contaminant present, the degree of weathering, the need for source removal, and the effect of source removal techniques on specific compounds. |
| Toluene | GC Method SW8020 | 10 µg/kg | | L | B | Same as benzene. |
| Ethylbenzene | GC Method SW8020 | 10 µg/kg | | L | B | Same as benzene. |
| Xylene | GC Method SW8020 | 30 µg/kg | | L | B | Same as benzene. |
| Trimethylbenzene isomers | GC Method SW8020 | 10 µg/kg | | L | B | Tracers to aid data evaluation on soil contamination and potential impact to ground water. |

TABLE 4.1 (Continued)

SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Soil

| Analysis | Method | Required Detection Limit | | Field or Laboratory | Analysis Classification* | Data Use |
|-----------------|-----------------|--------------------------|-----------|---------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | SW8310 | 330 µg/kg | | | |
| Napthalene | HPLC Method | SW8310 | 330 µg/kg | L | B | Quantitative analysis to determine the nature and extent of soil contamination |
| TOC | Modified SW9060 | 20 mg/kg | | L | B C | Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of fuel-related compounds in ground water is dependent upon the amount of TOC in phreatic soils; the rate of release of fuel-related compounds from the source to ground water is in part dependent on the amount of TOC in the unsaturated soil. |
| pH | E150.1 | 0.2 | | L | D | Aerobic and anaerobic processes are pH-sensitive. |
| TKN | E351.2 | -- | | L | D | Natural nutrient levels |
| Total Phosphate | E365 | -- | | L | D | Natural nutrient levels |

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

TABLE 4.1 (Continued)

SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Ground Water

| Analysis | Method | Required | | Field or Laboratory | Analysis Classification* | Data Use |
|----------------------|-----------------------|-----------------|--|---------------------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | Detection Limit | | | | |
| Depth to water | Water probe | 0.01 ft | | F | A | Hydrogeological characterization; well development. |
| Thickness of product | Oil/water probe | 0.01 ft | | F | A | To determine extent of potential continuing source to ground water, the mass of source contamination, and the need for source removal. |
| Temperature | E170.1 | 0.2°C | | F | A | Well development. |
| DO content | Downhole DO probe | 0.2 mg/L | | F | A | Data input to Bioplume II model; depleted levels generally indicate inhibited aerobic degradation and potential presence of anaerobic degradation processes; concentrations less than 1 mg/L correlate well to elevated dissolved-phase BTEX contamination. |
| pH | E150.1/direct reading | 0.2 | | F | A | Aerobic and anaerobic processes are pH-sensitive. |
| Benzene | GC Method SW8020 | 1 µg/L | | L | B | Primary compound-specific analytes used to estimate and monitor intrinsic remediation; used to determine nature and extent of contamination; the degree of |

TABLE 4.1 (Continued)

SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Ground Water

| Analysis | Method | Required | | Field or Laboratory | Analysis Classification* | Data Use |
|--------------------------------------------------------------|---------------------|-----------------|---|---------------------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | Detection Limit | | | | |
| Toluene | GC Method SW8020 | 1 µg/L | L | B | | weathering, and used to establish and demonstrate compliance with site-specific remediation goals. |
| Ethylbenzene | GC Method SW8020 | 1 µg/L | L | B | | Same as benzene. |
| Xylenes | GC Method SW8020 | 3 µg/L | L | B | | Same as benzene. |
| Trimethylbenzene isomers(1,2,3-TMB 1,2,4-TMB, and 1,3,5-TMB) | GC Method SW8020 | -- | L | B | | To monitor and correct for plume dilution effects in Bioplume II model setup. |
| Napthalene | HPLC Method SW8310 | 5 µg/L | L | C | | To determine nature and extent of such contamination; the degree of weathering; and to establish and demonstrate compliance with site-specific remediation goals. |
| Alkalinity | Colorimetric E310.2 | -- | F | A | | To verify that ground water samples are obtained from same system and to measure the buffering capacity of the aquifer. |
| Nitrate | Colorimetric E353.2 | 2 mg/L | F | A | | Secondary substrate (electron acceptor) for microbial respiration if |

TABLE 4.1 (Continued)

SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Ground Water

| Analysis | Method | Required | | Field or Laboratory | Analysis Classification* | Data Use |
|----------------|------------------------------------------------------------------------|--------------------|-------|------------------------|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | Detection Limit | Limit | | | |
| Sulfate | HACH Sulfa Ver 4 | -- | | F | A | oxygen is depleted; data input to Bioplume II model. Potential substrate for anaerobic microbial respiration; will be used semi-quantitatively when evaluating intrinsic remediation. |
| Carbon dioxide | HACH RSKSOP 114 modified (or 175) (CO ₂ Coulmeter) | -- | | F L | A | Carbon dioxide can be an electron acceptor for anaerobic microbial respiration; the presence of free carbon dioxide dissolved in ground water is unlikely given natural buffering capacities. If detected, concentrations will be compared to background levels to determine if they are elevated, which could suggest aerobic degradation. |

TABLE 4.1 (Continued)

SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Ground Water

| Analysis | Method | Required | | Field or Laboratory | Analysis Classification* | Data Use |
|------------------------------------------------------------|------------------------------|-----------------|--|---------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | Detection Limit | | | | |
| Methane | RSKSOP 147 114 Mod or 175 | -- | | L | C | The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis). If detected, concentrations will be compared to background levels to determine if they are elevated, which could suggest anaerobic degradation. |
| Total hydrocarbons (Extractable and volatile fractions) | GC Method SW8015 | -- | | L | C | To estimate the extent of contamination and to monitor the reduction in fuel-related contamination due to natural attenuation. |
| Ferrous iron (Fe^{2+}) | HACH 25140-25 | 0.06 mg/L | | F | A | May indicate an anaerobic degradation process as a result of depletion of other electron acceptors such as oxygen and nitrate. |
| Manganese | HACH | | | F | A | Potential substrate (electron acceptor) for microbial respiration if oxygen is depleted. |

TABLE 4.1 (Continued)

SOIL AND GROUND WATER ANALYTICAL PROTOCOL
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

Matrix: Ground Water

| Analysis | Method | Required | | Field or Laboratory | Analysis Classification* | Data Use |
|------------|--------|-----------------|--|---------------------|--------------------------|-----------------------------------------------------------------------------------|
| | | Detection Limit | | | | |
| Total Iron | HACH | | | F | A | Gross estimate of total iron in system; may be used in mass balance calculations. |
| Sulfide | HACH | | | F | A | Reduced species of potential electron acceptors used in BTEX degradation. |
| Nitrite | HACH | | | F | A | Reduced species of potential electron acceptors used in BTEX degradation. |

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

contamination, possibly sampled for laboratory analyses, and then composited for headspace readings. A maximum of two soil samples for laboratory analyses will be taken from soil borings SB1 and SB2, based on field headspace screening. At least one sample will be collected and analyzed from each of these borings. An estimated maximum total of four additional soil samples will be collected from the remaining soil borings based on the extent of apparent soil contamination (as indicated by olfactory, visual, or volatile organic analyzer inspection). Samples will be taken at 2-foot intervals for analytical analyses. Samples will be collected from approximately 5 to 7 feet bgs, from the capillary fringe, and upper portion of the saturated zone. Soil samples will be analyzed as prescribed in Table 4.1. Soil borings which exhibit apparent vadose zone soil contamination will be converted to combination 4-inch-diameter bioventing and ground water monitoring wells. All others, with the exception of either SB1 or SB2, will be converted to 2-inch-diameter permanent ground water monitoring wells. The new soil sampling and ground water monitoring well locations were selected to provide additional information about site stratigraphy, background concentrations, and the extent of the contamination downgradient of the KC-135 Crash Site.

Soil sampling will be conducted by qualified PARSONS ES scientists and technicians trained in the conduct of soil drilling, sampling, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan, including Appendix A, prior to sample acquisition and will have a copy available onsite for reference.

4.2.2 Ground Water Monitoring Well Construction and Development

An estimated total of 12 ground water monitoring wells will be installed in the soil borings at this site. Three of these wells (W-409S, W-409M, and W-409D) will be a nested well set designed to evaluate physical and chemical hydrogeologic conditions at three depths in the shallow aquifer. Additional well sets will be installed down-gradient of this location if laboratory BTEX results indicate ground water contamination at the intermediate or deep screened intervals. The remainder of the wells will be shallow with the screened intervals intersecting the ground water surface.

The shallow wells will be constructed through the hollow stem augers using 2-inch-diameter, flush-threaded, Schedule 40 polyvinyl chloride (PVC) well casing and screen. The screens will consist of 10-foot-long sections of 0.010-inch factory-slotted screen with bottom caps, and will be positioned with 5 feet extending below the water table. The top of the casing will be sealed with a locking, water-proof well cap. The surface completion will consist of an 8-inch-diameter, flush-mounted well box set in a concrete collar sloping away from the well box and matching the existing grade.

Shallow ground water monitoring wells completed in soil borings which exhibit an interval of soil contamination exceeding 2 feet above the water table will be constructed using 4-inch-diameter well casing and screen (in place of the standard 2-inch-diameter casing). The larger diameter casing will enable these wells to be used in the future as bioventing wells, in addition to ground water monitoring wells, if needed.

Deep wells will be constructed by first installing 8-inch diameter PVC surface casings, cemented in place, installed from the ground surface to approximately 30 feet bgs. The surface casing will minimize the potential for cross contamination from the upper part of the aquifer to the deeper portions of the aquifer during drilling and well installation. After the surface casing cement has set, an approximately 6-inch-diameter borehole will be advanced from the bottom of the surface casing to the top of the confining, silty clay unit at a depth of approximately 65 feet bgs. With the exception of the well screen placement, construction of 2-inch-diameter wells will then be completed using the same methods and materials as were described for the shallow wells. The screens for the intermediate and deep wells will be 5 feet long and will be positioned in approximately the middle and bottom of the shallow aquifer.

After the wells are completed, they will be developed by surging and pumping using a Teflon[®] bailer and pump. Well development will continue until a minimum of three casing-volumes of water have been removed from the wells and the pH, conductivity, and temperature do not fluctuate by more than 10 percent over one casing volume.

4.2.3 Ground Water Sampling

All 12 of the newly installed wells and 8 existing wells at the KC-135 Crash will be sampled to further delineate probable source areas of contamination, the areal extent of the dissolved-phase plume, changes in contaminant concentrations with time, and other hydrogeologic characteristics.

Emphasis will also be placed on defining the estimated extent of any remaining free fuel product that may act as a continuing source of ground water contamination. Although free product was detected on the ground water surface during initial investigations, free product has not been detected in any well after November. Free product can be physically identified using an oil/water interface probe. Moreover, any ground water samples showing a benzene concentration equal to or greater than 178 ppm (10 percent of its maximum solubility in water) will be operationally defined as fringe areas to free-phase contamination (or underlying significant residual soil contamination).

Figures 4.1 and 4.2 identify the locations of the proposed ground water monitoring wells, and Table 4.2 identifies the existing ground water monitoring wells that will be sampled as part of this characterization effort. Ground water samples taken as part of this field effort will be analyzed as prescribed in Table 4.1. Data from previous investigations will be incorporated into the final analysis to the extent practicable to avoid unnecessary duplication of field results. If encountered during drilling or ground water sampling, at least one free product sample will be recovered, if possible, and subjected to a full chemical constituent analysis to determine how free-phase fuel constituents will partition into the ground water and contribute to the dissolved-phase plume.

TABLE 4.2

SITE-SPECIFIC SAMPLING STRATEGY
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN

| Media | Sample Location | Analysis Classification* | Media | Sample Location | Analysis Classification* |
|-------|-----------------|--------------------------|----------|-----------------|--------------------------|
| Water | W-400 | A, B | Soil | SB1 | A, B, C |
| Water | W-401 | A, B, C | Soil | W-407 | A, B, C, D |
| Water | W-402 | A, B, C | Soil | W-408 | A, B |
| Water | W-403 | A, B | Soil | W-409S | A |
| Water | W-404S | A, B | Soil | W-409M | A |
| Water | W-405M | A, B | Soil | W-409D | A, B, C |
| Water | W-406D | A, B | Soil | W-410 | A |
| Water | W-407 | A, B, C | Soil | W-411 | A |
| Water | W-408 | A, B, C | Soil | W-412 | A |
| Water | W-409S | A, B, C | Soil | W-413 | A |
| Water | W-409M | A, B, C | Soil | W-414 | A |
| Water | W-409D | A, B, C | Soil | W-415 | A |
| Water | W-410 | A, B | Soil | W-416 | A, B, C, D |
| Water | W-411 | A, B, C | Soil Gas | W-404S | A, B |
| Water | W-412 | A, B | Soil Gas | W-408 | A, B |
| Water | W-413 | A, B | Soil Gas | W-409S | A, B |
| Water | W-414 | A, B, C | | | |
| Water | W-415 | A, B | | | |
| Water | W-416 | A, B, C | | | |
| Water | USGS4 | A, B, C | | | |

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited. Table 4.1 describes analysis classification requirements by medium.

4.2.4 Soil Gas Sampling

Soil gas sampling will be completed to determine the potential for lateral and upward diffusion of soil contamination in the soil-pore vapors. Soil gas samples will be withdrawn from ground water monitoring wells (W-404S, W-408, and W-409S), located within the contaminant plume, that have a portion of their screens positioned above the water table surface. Soil gas samples will be withdrawn, screened for fuel hydrocarbons, and analyzed for BTEX and TVH concentrations. Soil gas samples will be analyzed as described in Table 4.1.

4.2.5 Aquifer Testing

Aquifer testing was performed as part of the RI, and no additional testing is proposed as part of this site characterization (WW Engineering & Science, 1993). Hydraulic conductivity was estimated by performing slug tests at seven permanent monitoring wells (W-400 through W-406D). Results of these tests will be used to support quantitative fate and transport analyses using the Bioplume II model.

4.2.6 Surface Water Sampling

No surface water sampling is proposed for KC-135 Crash Site because the nearest surface water body is 3,000 feet from the source and the contamination has moved only 500 feet. In addition, no special ecological resources have been identified at or near the site. However, if fate and transport modeling indicates that contamination from the KC-135 Crash Site may impact surface water, additional analyses may be required.

4.3 SOURCE REMOVAL FEASIBILITY TESTING

It is not anticipated that engineered soil or ground water remediation will be required to reduce the source of BTEX contamination migrating away from the KC-135 Crash Site or to reduce potential exposures to these compounds. Results from the RI indicate that soil at this site has not been impacted by the fuel release. Free product originally present at the site has significantly decreased and has not been detected since 22 November 1991 (see Section 2).

In addition to intrinsic remediation, two active remediation methods will be considered during the RAP process if the proposed site characterization indicates unacceptable risk without engineered source removal. The technologies are *in situ* bioventing of soils, and air sparging to promote VOC removal from the ground water and to add dissolved oxygen (DO) to the aquifer. Because of the similarity in geology and hydrogeology between the KC-135 Crash Site and another on-base site, OT45, the results of pilots tests performed for the RAP at OT45 will be applicable to the KC-135 Crash Site, if they are necessary (PARSONS ES, 1994).

SECTION 5

REMEDIAL OPTION EVALUATION AND RAP REPORT

Upon completion of the field work in support of the risk-based approach, a quantitative source and release analysis using simple partitioning models and Bioplume II will be completed to determine the fate and transport of fuel-hydrocarbon-contamination at the site and to estimate the effectiveness of intrinsic remediation. For example, the Bioplume II model will be used to investigate whether natural attenuation is occurring at the site, and if so, to what extent this process is minimizing contaminant migration. Based upon model predictions of contaminant concentration and distribution in various media through time, an exposure pathway assessment will be conducted. If the model predictions suggest that contamination may exist at or migrate to an exposure point, the exposure pathway will be considered complete. To identify the type and magnitude of remediation that may be required to protect human health and the environment, appropriate numerical remediation goals for each environmental media and COC will be identified. Data from the models used to determine whether an exposure pathway may be complete will also be used to estimate exposure-point concentrations using the guidance developed by EPA (1992b) concerning reasonable maximum exposure concentrations.

A qualitative screening of the various remedial technologies will be conducted to narrow the list to only those that are likely to address the principal threats posed by the site. These remedial technologies will then be combined as necessary to create a remedial alternative (e.g., alternative 1: intrinsic remediation, long-term monitoring, and land use restrictions). An iterative, quantitative evaluation of the effectiveness of these final remedial alternatives in achieving these site-specific remediation goals will then be completed.

5.1 RAP Objectives

The objectives of this field test project and the RAP effort are to evaluate, select, design, and implement the remedial alternative that:

- Meets the cleanup goals for the site;
- Is permanent or at least achieves the highest degree of long-term effectiveness possible; and
- Is cost effective in that it achieves the best balance between long-term effectiveness and cost.

To meet these objectives, the approach for determining appropriate remedial action at contaminated sites presented in the State of Michigan's Act 307 will be applied. Under this act, a three-tiered approach (Type A, B, or C) to determining cleanup criteria at contaminated sites is described. Compliance with Type A criteria is achieved when the concentrations of contaminants in any affected environmental media are below local background concentrations or the analytical method detection limit (MDL) for the contaminant. Types B and C are risk-based and differ by the type of exposure assumed, the point of compliance, and the post-cleanup responsibilities and requirements. Under Type B, a residential (or life-long) exposure is assumed, the point of compliance is assumed to be everywhere on the site, and there are no post-cleanup requirements or responsibilities. Type C remediation assumes an industrial exposure, moves the point of compliance to the point of exposure by human or environmental receptors, and includes post-cleanup land use restriction documentation requirements.

A Type C remediation at the KC-135 Crash Site will be pursued as part of this field test project. The RAP prepared as part of this field test project will satisfy the requirements of Operational Memorandum #14 (MDNR ERD, 1994), which presents the algorithms to be used in Type C remediations and the resultant cleanup criteria based on the algorithms. The RAP will contain complete information on all aspects of the final remedial alternative recommended for the site, including quantitative and other evaluation data, long-term monitoring requirements, and any long-term land use restrictions.

5.2 Major Components of the RAP

The following sections briefly present the major components of a RAP. The RAP report will contain detailed information on field and laboratory analytical results; quantitative source, release, fate, and transport analyses; exposure-point concentrations; toxicity data; risk characterization information; identification of appropriate remediation goals; and the factors affecting and methods used to evaluate potential remedial alternatives for the site. The RAP will also recommend and present a design for the most appropriate remedial alternative for the site. Construction of required source removal systems will begin immediately following base and regulatory approval of the RAP document.

5.2.1 Data Presentation

The RAP will be structured to clearly and concisely present the approach and results of each of the major steps completed to select, design, and implement an appropriate remedial alternative for the site which minimizes risks to human health and the environment to the extent practical. Figure 5.1 presents an example RAP outline that will guide the development of data and supporting text. The RAP will be structured to place emphasis on the results of field work, risk analysis, and remedial alternative evaluation. Detailed information on the methodologies used in each of these steps will be contained in appendices to the RAP. This approach should streamline the final report to focus on the results of the evaluation. In this way, regulators and other decision-makers will not have excessive documentation to review to determine whether the recommended remedial alternative meets all the stated objectives of the project.

FIGURE 5.1

**EXAMPLE RAP REPORT OUTLINE
RAP WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
KC-135 CRASH SITE, WURTSMITH AFB, MICHIGAN**

Executive Summary

- 1.0 Introduction**
 - 1.1 Purpose and Scope**
 - 1.2 Site Background**
 - 1.3 Report Organization**
- 2.0 Site Description**
 - 2.1 Physical Setting**
 - 2.2 Nature and Extent of Contamination**
 - 2.2.1 Previous Investigations**
 - 2.2.2 Recent Data**
 - 2.3 Indicator Analyte Data**
 - 2.4 Discussion of Evidence of Intrinsic Remediation**
- 3.0 Evaluation Methods and Criteria**
 - 3.1 Remedial Action Objectives**
 - 3.2 Potential Exposure Pathways for Human/Ecological Receptors**
 - 3.3 Site-Specific Fate and Transport Models**
 - 3.4 Site-Specific Cleanup Goals**
 - 3.5 Review of Evaluation Criteria**
 - 3.5.1 Protectiveness**
 - 3.5.2 Implementability**
 - 3.5.3 Cost**
- 4.0 General Description of Potential Remedial Alternatives (Examples)**
 - 4.1 Alternative 1: Intrinsic Remediation/Long-term Monitoring**
 - 4.2 Alternative 2: Bioventing to Remove Soil Source(s)/Intrinsic Remediation/Long-Term Monitoring**
 - 4.3 Alternative 3: Remove Free Product/Intrinsic Remediation/Long-Term Monitoring**
 - 4.4 Alternative 4: Soil Vapor Extraction/Ground Water Pump and Treat**
- 5.0 Comparative Analysis of Remedial Alternatives**
 - 5.1 Protectiveness**
 - 5.2 Implementability**
 - 5.2.1 Technical**
 - 5.2.2 Administrative**
 - 5.3 Cost**
 - 5.3.1 Capital Costs**
 - 5.3.2 Operating Costs**
 - 5.3.3 Present Worth Cost**
- 6.0 Recommended Remedial Alternative**
- 7.0 References**

- Appendix A: Data Evaluation for Risk Analysis**
- Appendix B: Development of Site-Specific Cleanup Goals**
- Appendix C: Quantitative Exposure Assessment Data (Model Simulations)**
- Appendix D: Long-Term Monitoring Plan**
- Appendix E: Operation and Maintenance Plan (if applicable)**

5.2.2 Data Evaluation and Modeling

Data from field work conducted in support of the risk-based field test project that will be used in quantitative analyses will be gathered and sorted by environmental medium. Any analytical data used in this field test project will be evaluated in terms of their quality. This data useability review will include a review of the analytical methods, quantitation limits, and other factors important in determining the precision, accuracy, completeness, and representativeness of the final data set. The outcome of this data evaluation will be a data set appropriate to support quantitative fate and transport analyses and risk analysis. The data evaluation methods defined by EPA (1989b) in OSWER Directive 9285.7-01a *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (EPA/540/1-89/002) and OSWER Directive 9285.7-09a *Guidance for Data Usability in Risk Assessment* (EPA, 1992a) will be used as appropriate. By using the analytical methods and quantitation limits defined in this work plan (see Table 4.1), the data collected during the field work phase of this field test project are designed to satisfy the rigorous data requirements of quantitative fate and transport modeling and risk analysis. Results of this data evaluation will be summarized in the RAP report. Data will be used as input parameters to the various quantitative models discussed in Section 3.2 and 3.3 and, as necessary, to explore potential exposure pathways that may or will be completed at the site. Models which require a single point-concentration value will use exposure-point concentrations developed using the EPA (1992b) *Supplemental Guidance to RAGS: Calculating the Concentration Term* (Publication 9285.7-081). This guidance is designed to assist in the development of an exposure concentration that represents the highest exposure that could reasonably be expected to occur for a given exposure pathway. This value is intended to account for both the uncertainty in environmental data and the variability in exposure parameters. This approach is consistent with that recommended in Operational Memorandum #14 (MDNR ERD, 1994).

More complex models such as Bioplume II do not require single-point values. In these cases, unadjusted field data will be used to simulate the fate and transport of contamination in the ground water. If model predictions demonstrate that an exposure pathway involving ground water is not complete, it will be unnecessary to develop exposure-point concentrations to compare to appropriate cleanup goals. Conversely, if model predictions show that an exposure pathway involving ground water is or may be completed, data from model sensitivity runs at the point of exposure will be statistically evaluated to determine a single-point exposure concentration. The goal of this approach is to factor model uncertainty into the development of an exposure-point concentration that is most representative of the site. Again, EPA (1992b) guidance will be followed to develop exposure concentration values suitable for comparison to appropriate cleanup goals.

5.2.3 Method of Risk Analysis

The techniques which will be used in the risk analysis for KC-135 Crash Site to identify which remedial alternative best addresses the risks associated with a site will be analogous to those used to evaluate long-term risks associated with various remedial alternatives rather than those used to complete a baseline risk assessment. The method to be used as part of this field test project consists of three key steps: (1) identifying

site-specific exposure pathways that are either complete or not complete; (2) developing appropriate remedial concentration goals for COCs based on site-specific considerations; and (3) determining the type and magnitude of remedial action required to meet cleanup goals for the site. The risk analysis method inherently includes the four basic components of a traditional risk assessment (i.e., data evaluation, exposure assessment, toxicity assessment, and risk characterization) in the three steps described above. Moreover, the risk-based approach to remediation improves upon traditional approaches by using the tools of risk assessment to identify which remedial alternative achieves the best balance between risk reduction and cost. Figure 5.2 summarizes the risk analysis method. This method is consistent with that required to attain a Type C remediation.

5.2.3.1 Exposure Pathway Evaluation

As described in Section 3, an exposure assessment identifies the potential human and ecological receptors that could come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed pathway of exposure, there must be a source of contamination, a mechanism of release, a receptor, and a route through which the contamination could reach the receptor. The risk-based approach to remediation is designed to use quantitative field data and models to characterize both the existing nature and extent of contamination and what effect various remedial technologies such as intrinsic remediation will have on the fate and transport of contaminants in the environment through time. The CSM presented in Section 3 of this work plan identifies the potential source, potential release mechanisms, current and potential future receptors, exposure points, and exposure routes that may be involved in current or future exposure scenarios for the site. This CSM was developed to ensure that adequate data are collected to support a quantitative evaluation of the potential for exposure pathway completion at the site.

Field data and model simulations which account for the physical setting and characteristics of the site will be used to estimate whether any exposure pathway is completed and, if so, to quantify the COC concentrations at the point of exposure. The method of risk analysis to be used as part of this field test project hinges on achieving remediation goals for each environmental media. Appropriate cleanup criteria to demonstrate attainment of Type C criteria will be identified and defined to be protective of human health and the environment given site conditions.

If an exposure pathway is determined to be completed, the exposure assessment will be expanded to calculate exposure-point concentrations. As discussed in Section 5.2.2, field data and model simulation results will be statistically evaluated using EPA (1992b) guidance on how to calculate a single-point concentration level that represents the highest concentration to which a receptor could reasonably be exposed given site conditions. Using modeled data in the calculation of the exposure-point concentration is designed to account for the positive effects of natural attenuation processes that may be operating at the site. This approach also appears to be consistent with the requirements for a Type C remediation as stated in Operational Memorandum #14 (MDNR ERD, 1994).

5.2.3.2 Identifying Cleanup Goals

To evaluate, select, and design an appropriate remedial alternative for the site, long-term target remediation cleanup criteria must be defined. These remediation goals will be those shown in the tables attached to Operational Memorandum #14 (for Type C remediation) and Operational Memorandum #8 (Type B remediation) (MDNR ERD, 1994). Type C criteria will be used as the remediation goals for all onsite concentrations. Type B criteria will only be used as the remediation goals for ground water at the downgradient point of compliance. Use of these values will eliminate the need to develop chemical-specific, site-specific cleanup criteria. However, if circumstances warrant, alternative remediation goals may be developed for comparison purposes.

Both Type B and Type C cleanup criteria include three separate categories which vary by the type of criteria and the media. MDNR specifies that the lowest of the three values should be used in risk analysis. For this project, a separate comparison of representative contaminant concentrations to each of the three criteria will be made. Seaprate comparisons to each of the categories will help define the basis for the need for remediation. For example, if remediation of ethylbenzene is based upon its concentration exceeding a GSI value and it has been demonstrated that ethylbenzene will no reach a surface water interface, then the need for and level of remediation may need to be re-evaluated.

Operational Memoranda #8 and #14 list both the algorithms and resultant cleanup criteria values. Included in the algorithms are chemical-specific toxicity values developed by EPA. The toxicity values are continually reviewed and updated monthly. Criteria used in the risk analysis will be recalculated using the most current, updated toxicity information. If values calculated using updated toxicity values differ from those listed in the tables accompanying Operational Memoranda #8 and #14, the cleanup criteria calculated using the most current, updated toxicity values will be used.

The sources for toxicity information will be limited to IRIS (Micromedix, 1994) and the Health Effects Assessment Summary Tables (HEAST) (EPA, 1994). The most current toxicity values for COCs present at the KC-135 Crash Site will be input into the algorithms presented in Operational Memorandum #14 to ensure that the cleanup criteria listed in the tables of the memorandum reflect the most updated toxicity information. Cleanup criteria listed in the table that reflect outdated toxicity information will be replaced with criteria based on updated toxicity information. This method is consistent with Operational Memorandum #14.

Operational Memorandum #14 does not specify that dermal toxicity values should be used in evaluating dermal pathways of exposure. However, modifying oral toxicity values to account for dermal toxicity is based on conservative assumptions, and will be included as appropriate toxicity information. Sources for information on dermal modification factors will include Agency for Toxicological Studies and Disease Registry (ATSDR) Toxicological Profiles, EPA Dermal Guidance (EPA, 1992d), RAGS (EPA, 1989b), and best professional judgment.

Any uncertainties associated with each of the steps will be identified and discussed in the RAP. The potential impact of these uncertainties on the development of appropriate cleanup goals for the site will also be qualitatively evaluated.

5.2.3.2.1 Air

Operational Memorandum #14 acknowledges the potential for unacceptable risks via the inhalation pathway, but specifies that risks via this pathway will not be addressed through the existing criteria unless the COCs present at the site are defined as "special concern materials." Such materials include contaminants that may pose risks via the inhalation pathway but not the oral pathway (e.g., hexavalent chromium, cadmium, and nickel) and materials with special characteristics (e.g., friable asbestos). If none of these materials are present at a site, then exposure control measures which are protective for other routes of exposure will be deemed protective for the inhalation pathway. In these cases, a narrative assessment for the inhalation pathway will be sufficient.

The contaminants detected at the KC-135 Crash Site will be evaluated to determine if any materials of special concern are present. If none are present, a narrative assessment will be completed. If any materials of special concern are present, a more detailed assessment of inhalation risks will be performed. The risk evaluation performed as part of the RI found the inhalation pathway to be insignificant (WW Engineering & Science, 1993).

5.2.3.2.2 Soil

Operational Memorandum #14 (MDNR ERD, 1994) includes a table of cleanup criteria that defines Type C cleanup criteria. These Type C cleanup criteria are based on an industrial land use assumption. As noted earlier, the KC-135 Crash Site is assumed to meet the requirements of an industrial site as defined in Operational Memorandum #14 (MDNR ERD 1994). The only exposure pathway that is likely to be incorporated into the soil remediation goals for the BTEX compounds is incidental ingestion of and dermal contact with soil. The concentration terms based on field data described in Section 5.2.2 will be compared to the Type C soil criteria (updated using current toxicity data, if necessary), to determine if current concentrations exceed the Type C criteria. If current concentrations exceed the criteria, remedial technologies for soil will be evaluated to determine which are sufficient to attain Type C criteria.

Cross-media contamination of ground water from contaminated soil will also be factored into the development of soil cleanup goals to ensure that soil is remediated to a level protective of ground water quality. Fate and transport models, such as the Summers model and the air dispersion model discussed in Section 3.3, may be incorporated into this analysis to ensure that the selected remedial alternative minimizes cross-media contamination. Operational Memorandum #14 lists fate and transport modeling as an acceptable method for establishing soil cleanup criteria that are protective of ground water.

As previously noted, soil cleanup levels are assumed to adequately reduce risks from the inhalation pathway, unless contaminants of special concern are present. A

determination of whether any of the contaminants at the KC-135 Crash Site are of special concern and an appropriate analysis will be completed and documented in the RAP.

5.2.3.2.3 Ground Water

The table included with Operational Memorandum #14 defines the Type C cleanup criteria for ground water. As for soil, the concentration terms based on field data described in Section 5.2.2 will be compared to the ground water criteria to determine if current concentrations exceed the Type C criteria. If current concentrations exceed the criteria, modeled future onsite concentrations will also be compared to the Type C criteria. In these cases, the point of compliance will be the onsite wells because this is assumed to be the point of exposure for human and environmental receptors under the industrial land use assumption.

In addition to the criteria for a Type C remediation, offsite ground water concentrations must also meet the residential criteria described in Operational Memorandum #8-Type B Criteria Rules, unless it can be established that the downgradient ground water will not be used for domestic purposes. For this field test, it will be assumed that ground water concentrations at and downgradient of the point of compliance will be compared to Type B criteria. In this case, the point of compliance will be the property boundary closest to the site. While the property boundary is not the most likely point of exposure for human and environmental receptors, it is a conservative assumption that is consistent with implementation of any required land use controls. Thus, the remediation approach for the KC-135 Crash Site will be sufficient to attain Type C criteria for shallow ground water within and immediately downgradient of the site and Type B criteria for ground water at and beyond the property boundary.

Several different ground water criteria are listed in both the Type B and Type C criteria tables. These include health-based drinking water values, aesthetic drinking water values, and GSI values. To comply with Act 307, the lowest of the three criteria must be met. However, as part of this risk-based field test, all three cleanup criteria will be compared to site concentrations in the RAP. Results of this analysis will demonstrate how effective each remedial technology would be at meeting each of the three categories of cleanup criteria.

The GSI values listed in both the Type B and Type C criteria tables establish ground water criteria which are protective of surface water. Use of these GSI values will address concerns about cross-media contamination from ground water to surface water as well as any concerns about ecological receptors. Because the nearest surface water body is located 3,000 feet downgradient of the site, the appropriate concentration to compare to the GSI value is future modeled ground water concentrations at a point near the Au Sable River. It is extremely unlikely that the dissolved-phase plume will migrate this distance due to natural attenuation. These GSI values will only be used as cleanup criteria if model results suggest that contamination could reasonably migrate to within 500 feet of the Au Sable River.

5.2.3.2.4 Surface Water

The GSI values discussed above establish ground water criteria which are protective of surface water. The RI for the KC-135 Crash Site (WW Engineering & Science, 1993) determined that the surface water pathway was not complete. As stated in Sections 3 and 5.2.3.2.4 of this work plan, the surface water pathway is likely to remain incomplete. However, the GSI values will be retained in the risk analysis to comply with MDNR guidance and to address any concerns about cross-media contamination and risks to ecological receptors.

5.2.3.3 Risk Determination

The goal of this field test is not to determine whether remedial action is warranted at the site, but rather to determine the type and magnitude of remedial action required to minimize risks to human health and the environment to the maximum extent practicable. The potential risks to human receptors will be determined both by comparing the calculated exposure concentration derived from field data and quantitative fate and transport analyses to the medium-specific cleanup criteria. If this comparison indicates that natural attenuation of site COCs is occurring and is sufficient to reduce the potential risks to human health and the environment to acceptable levels, Parsons ES may recommend implementation of natural attenuation with long-term monitoring as the preferred remedial alternative. The RAP prepared to demonstrate the risk-based approach to remediation will satisfy the state procedural, technical, and documentation requirements of a RAP.

5.2.3.4 Evaluation of Source Removal/Risk Reduction Options

To provide adequate data and analyses in support of the selection, design, and implementation of an appropriate remedial alternative for the KC-135 Crash Site, it will be necessary to critically evaluate single or combined remedial technologies in terms of long-term effectiveness, implementability, and cost. These evaluation criteria have been adapted from those recommended by EPA (1991c) to select remedies for Superfund sites. Field data, quantitative fate and transport modeling designed to explore the potential effectiveness of natural attenuation processes, and several other institutional and engineering technologies will be evaluated for their risk reduction potential. Combinations of institutional controls and cost-effective site remediation methods will be evaluated following the RAP process described in this section. Based on guidance from AFCEE, a minimum of three options will be evaluated for the site. Each option will be evaluated against three primary criteria: effectiveness in protecting human health and the environment, implementability, and cost.

Effectiveness - Each remedial alternative will be analyzed to determine how effectively it will protect both current and potential future receptors from potential risks associated with COCs. This analysis will be based on determining whether the remedial alternative can achieve and maintain final cleanup goals. Protectiveness will also include permanence and ability to reduce contaminant mass, volume, and toxicity. Section 5.2.3 provides a more detailed description of the risk methods that will be used to determine the adequacy of protection.

Implementability - The technical implementation of each remedial option will be evaluated. The expected technical effectiveness of each remedial alternative will be described. Potential shortcomings and difficulties in construction, operations, and monitoring will be presented and weighed against perceived benefits. The administrative implementation (regulatory and community acceptance) of each remedial approach also will be discussed. This is an important element of the RAP, particularly when intrinsic remediation is determined to be the most cost-effective method of risk reduction.

Cost - The estimated cost of each remedial option will be presented. Both capital and operating costs will be estimated along with a present-worth cost estimate for the predicted operating life of each option. Cost assumptions will be clearly stated, and the cost sensitivity of assumptions will be discussed.

It is important to note, however, that the most effective remedial technology or remedial alternative may not be the most cost-effective option for the site. Because the objective of this project is to identify, design, and implement the most cost-effective remedial alternative at the KC-135 Crash Site, it will be necessary to apply the test of cost effectiveness. A cost-effective remedial alternative is one that achieves the best balance between long-term effectiveness and cost of all the remedial alternatives which meet the cleanup objectives for the site. The test of cost effectiveness may be more extensive for a range of remedial alternatives which vary only in degree of long-term effectiveness, but which will all achieve the site cleanup goals. The remedial alternative which achieves the site cleanup goals at the lowest cost will be identified. The total cost for the other remedial alternatives will also be estimated, and all remedial alternatives will be ranked according to their degree of long-term effectiveness. The remedial alternative that provides the best balance between long-term effectiveness and cost would be the most cost-effective.

The following sections describe the remedial options that will, at a minimum, be considered for the KC-135 Crash Site in accordance with the statement of work (SOW) and subsequent AFCEE project direction.

5.2.3.4.1 Intrinsic Remediation Only with Long-Term Monitoring

Fate and transport models described in Section 3.2 and 3.3 will be used to estimate the natural reduction of COCs due to biodegradation, adsorption, and dilution. The ability of this remedial option to naturally reduce risk under the scrutiny of long-term monitoring will be described. If sufficient risk reduction cannot be achieved through intrinsic remediation alone, the potential for unacceptable risk will be discussed along with institutional controls which could be implemented to eliminate or reduce contact between the COCs and any at-risk receptors.

5.2.3.4.2 Limited Source Removal

If the intrinsic remediation option does not provide adequate protection of human health or the environment, additional removal of the contaminant source will be required. Even if intrinsic remediation appears to be protective, the uncertainties of fate and transport models may necessitate that some level of active remediation be

completed to reduce uncertainties associated with the long-term source of contamination. In these situations, the value of low-cost source removal technologies such as bioventing or biosparging will be evaluated. The selection of an appropriate source removal action will begin with a review of the site cleanup goals for soil and ground water. Using these cleanup goals, it will be possible to estimate the amount of additional source removal required to minimize risks to potential receptors and to protect environmental resources. In the case of downgradient ground water contamination, the Bioplume II data set will be modified to include the reduced source concentrations anticipated from the remedial option. The resulting reductions in soil and downgradient plume concentrations will then be compared against site-specific cleanup goals. Source removal will be increased until predicted concentrations are significantly less than the cleanup goals. In some cases, two or more source removal technologies will be integrated in this option.

5.2.3.4.3 Intensive Source Removal and Ground Water Pumping

Immediate reductions in contamination can be achieved through more intensive source removal options such as soil vapor extraction and the extraction and treatment of contaminated ground water. Although this intensity of treatment may not be required based on the current or future risks posed by site contaminants, AFCEE has requested that the benefits and additional costs of intensive treatment be evaluated in the RAP.

5.2.4 Selection of a Recommended Approach

Based on an evaluation of the protectiveness, implementability, and cost of each option, Parsons ES will recommend the option which provides the greatest protection for the lowest cost. If remediation of the source area is recommended, a conceptual design of the remediation system will be prepared and included in the RAP for Air Force and regulatory review. If intrinsic remediation is an integral part of the recommended option, a long-term monitoring plan will be developed to ensure both soil and ground water contamination are decreasing according to the remediation strategy.

5.2.5 Long-Term Monitoring Plan

Upon completion of the field work phase of this field test project, quantitative fate and transport models will be coupled with the CSM to complete and exposure assessment for the site. As described in this work plan, a tiered approach will be used to assess the potential effectiveness of various remedial alternatives at reducing or eliminating risks to potential receptors. If this analysis indicates that intrinsic remediation is sufficient to reduce the potential risk to human health and the environment, the most cost-effective remedial alternative for the site will be intrinsic remediation and long-term monitoring. A site-specific, long-term monitoring plan will be included as part of the RAP report which specifies the location of sentry and point-of-compliance wells and sampling frequencies necessary to demonstrate long-term effectiveness and permanence of the selected remedial alternative.

If quantitative data analysis indicates that intrinsic remediation will be insufficient alone to minimize receptor risks, other innovative source removal technologies such as bioventing or biosparging will be evaluated. The reduction of source and dissolved COCs that should result from additional remedial activities will be used in the quantitative fate and transport analyses for the site. Thus, the models will be used to predict exposure pathway completion and exposure-point concentrations resulting from supplementing intrinsic remediation with other source removal technologies. Again, once the most cost-effective remedial alternative is identified, the RAP will include a long-term monitoring plan which will contain any recommended plans for extended tests or sampling required to demonstrate the anticipated long-term effectiveness and permanence of the selected remedial alternative.

Following the implementation of any required source removal technologies at the site, Parsons ES will operate the source removal system for a total of 600 days. The 600 day limit is a contractual issue, however, most source removal technologies will significantly reduce BTEX concentrations in 600 days. At the end of the 600 days of treatment, Parsons ES will return to the site and resample soils and ground water in the source area to determine the degree of COC removal and evaluate the potential impact of source removal on the long-term fate and transport of dissolved- or vapor-phase contamination. A letter report will be prepared outlining the interim source removal results, the potential impact on the ground water plume and making recommendations for continued source removal if required.

5.3 Regulatory Coordination Strategy

The risk-based approach described in this work plan conforms to the overall approach for determining remedial actions as established in Act 307 of the State of Michigan. In particular, the procedures described in Operational Memoranda #8 and #14 will be followed to meet the requirements of a Type C remedial action.

The RAP will serve as the primary document for obtaining regulatory approval for the risk-based remediation approach. This document will contain all of the supporting data to satisfy the requirements of relevant guidance material from the State of Michigan (i.e., Operational Memoranda #8 and #14), and will provide sufficient evidence to state regulatory authorities to support the selection of the recommended remedial alternative. The RAP will provide quantitative evidence of intrinsic remediation and compare expected cleanup levels to defined cleanup goals for each affected environmental medium. If source removal is required, the RAP will provide a conceptual design that is in sufficient detail to gain regulatory approval to proceed with the remediation. A long-term monitoring plan will be provided to ensure that the predictions of fate and transport modeling can be verified and that COCs do not migrate at concentrations which could cause an unacceptable risk to human or ecological receptors. Sentry and point-of-compliance wells will be established to verify that intrinsic remediation is occurring and that plume migration is limited.

Following AFCEE and base review of the draft RAP, their comments will be incorporated into a final draft for regulatory review and approval. When the final draft is completed, AFCEE and Parsons ES will provide a technical presentation to base officials and regulatory agencies to familiarize them with the key findings and recommendations of the RAP. Copies of the RAP will be provided to regulators at the meeting and a 30 day review will be requested.

SECTION 6

PROPOSED PROJECT SCHEDULE

The following timeline (Figure 6.1) details the proposed duration of and date of completion for each of the major tasks involved in evaluating, selecting, designing, and implementing a remedial alternative for the KC-135 Crash Site which minimizes contaminant migration and risks to potential receptors. Each of these major tasks is described in other sections of this work plan.

SECTION 7

REFERENCES

- Abdul, A.S. 1988. "Migration of Petroleum Products through Sandy Hydrogeologic Systems," *Ground Water Monitoring Review*, Fall, p. 73-81.
- American Petroleum Institute. 1980. The Migration of Petroleum Products in the Soil and Ground Water, Principles and Countermeasures. American Petroleum Institute Publications 1628.
- Borden, R.C., and Bedient, P.B. 1986. "Transport of Dissolved Hydrocarbons Influenced by Oxygen Limited Biodegradation: Theoretical Development," *Water Resources Research*, vol. 22, no. 13. p. 1973-82.
- Bouwer, E.J., 1992. "Bioremediation of Subsurface Contaminants," In R. Mitchell, editor, *Environmental Microbiology*, Wiley-Liss, New York, New York.
- Bruce, L., Miller, T., and Hockman, B. 1991. "Solubility versus Equilibrium Saturation of Gasoline Compounds - A Method to Estimate Fuel/Water Partition Coefficient Using Solubility or K_{oc} ," In A. Stanley, editor, *NWWA/API Conference on Petroleum Hydrocarbons in Ground Water* p. 571-582.
- Chiang, C.V., Salanitro, J.P., Chai, E.Y., Colthart, J.D., and Klein, C.L. 1989. Aerobic biodegradation of benzene, toluene, and xylene in a sandy aquifer: data analysis and computer modeling, *Ground Water* 27(6):823-834.
- Domenico, Patrick A., and Schwartz, Franklin W. 1990. *Physical and Chemical Hydrogeology*. New York: John Wiley & Sons.
- Engineering-Science, Inc. 1994. *Health and Safety Plan for Risk-Based Remediation Demonstrations*. Prepared for the US Air Force Center for Environmental Excellence. June.
- Engineering-Science, Inc. 1994. Project Management Plan AFCEE Risk-Based Demonstration, Appendix F - Quality Assurance Project Plan for Risk-Based Approach for Fuel Spill Remediation, December.
- Engineering-Science, Inc. 1994. Work Plan for a Remedial Action Plan in Support of the Risk-Based Approach to Remediation at Site OT45, Wurtsmith Air Force Base, Oscoda, Michigan (in progress).
- Hvorslev M.J. 1951. Time Lag and Soil Permeability in Ground-Water Observations. United States Corps of Engineers Waterways Experiment Station Bulletin 36 Vicksburg Mississippi 50 p.

- Lee, M.D. 1988. "Biorestitution of Aquifers Contaminated with Organic Compounds." *CRC Critical Reviews in Environmental Control*, v. 18. p. 29-89.
- Malone, D.R., Kao, C.M., and Borden, R.C. 1993. "Dissolution and Biorestitution of Nonaqueous Phase Hydrocarbons: Model Development and Laboratory Evaluation," *Water Resources Research* 29(7):2203-2213.
- Micromedex, Inc. 1994. Toxicology, Occupational Medicine, and Environmental Series (TOMES) Plus Database, Vol. 17. Denver, Colorado.
- Michigan Department of Natural Resources (MDNR), Environmental Response Division (ERD) Staff. 1990. Interoffice Communication, To: All Environmental Response Division Field Staff, From: James G. Truchan, Chief Environmental Response Division, Subject: Act 307 Rules Implementation Manual. November 30.
- Michigan Department of Natural Resources (MDNR), Environmental Response Division (ERD) Staff. 1994. Interoffice Communication, To: Environmental Response Division Staff, From: Alan J. Howard, Chief, Environmental Response Division, Subject: Operational Memorandum #14: Generic Remedial Action Plans Using Industrial Site Risk Assessment Cleanup Criteria; Other Requirements for Type C Remedial Action Plans, June 21.
- Michigan Department of Natural Resources (MDNR), Environmental Response Division (ERD) Staff. 1994. Interoffice Communication, To: Environmental Response Division Staff, From: Alan J. Howard, Chief, Environmental Response Division, Subject: MERA Operational Memorandum #8, Revision 3 -- Type B Criteria Rules 299.5709, 299.5711(2), 299.5711(5) and 299.5713. February 4.
- Miller, Ross N., Downey, Douglas C., Carmen, Victoria A., Hinchee, Robert E., Leeson, Adrea. "A Summary of Bioventing Performance at Multiple Air Force Sites." *Proceedings of NGWA/API Petroleum Hydrocarbon Conference*, Houston, TX, November 1993, p.397-411.
- Rafai, H.S., Bedient, P.B., Wilson, J.T., Miller, K.M., and Armstrong, J.M. 1988. "Biodegradation Modeling at Aviation Fuel Spill Site," *Journal of Environmental Engineering*, v. 114, no. 5, p. 1007-1029.
- Rama Rao & Alfred, Inc. 1992. *Final Study Report Hydrogeological Survey, Wurtsmith Air Force Base, Oscoda, Michigan*. May 22.
- US Air Force. 1993. Preliminary Final Environmental Impact Statement, Disposal and Reuse of Wurtsmith Air Force Base, Michigan. Internal Working Draft, Not for Public Release, June 1993.
- US Air Force Center for Environmental Excellence. 1994. *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential*. February.
- US Environmental Protection Agency (EPA). 1981. *Evaluation Guidelines for Toxic Air Emissions from Land Disposal Facilities*. Office of Solid Waste.
- US Environmental Protection Agency (EPA). 1986. *Measurement of Gaseous Emission Rates from Land Surfaces Using an Emission Isolation Flux Chamber*. User's Guide Prepared by M.R. Klenbusch under EPA Contract No. 68-02-3889.

- US Environmental Protection Agency (EPA). 1987. 52 *Federal Register* 8706, March 19.
- US Environmental Protection Agency (EPA). 1989a. *Determining Soil Response Action Levels Based On Potential Contaminant Migration to Ground Water: A Compendium of Examples*. EPA/540/2-89/057 (October).
- US Environmental Protection Agency (EPA). 1989b. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A), Interim Final*. Publication EPA/540/1-89/002.
- US Environmental Protection Agency (EPA). 1991a. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim*. Publication 9285.7-01B
- US Environmental Protection Agency (EPA). 1991b. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives)*. Publication 9285.7-01C.
- US Environmental Protection Agency (EPA). 1991c. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*. Memorandum from Don R. Clay, Assistant Administrator of the Office of Solid Waste and Emergency Response, OSWER Directive 9355.0-30.
- US Environmental Protection Agency (EPA). 1992a. *Guidance for Data Usability in Risk Assessment (Part A)*. Office of Emergency and Remedial Response. Publication 9285.7-09a (April).
- US Environmental Protection Agency (EPA). 1992b. *Supplemental Guidance to RAGS: Calculating the Concentration Term*. Office of Solid Waste and Emergency Response. Publication 9285.7-081.
- US Environmental Protection Agency (EPA). 1992c. *Air/Superfund National Technical Guidance Study Series: Guideline for Predictive Baseline Emissions, Estimation Procedures for Superfund Sites*. Office of Air Quality. Publication EPA-450/1-92-002.
- US Environmental Protection Agency. 1992d. *Dermal Exposure Assessment: Principles and Applications*. Office of Health and Environmental Assessment, Washington, D.C. 20460. Publication No. EPA/600/8-91/011B. January 1992 Interim Report.
- US Environmental Protection Agency (EPA). 1994. *Health Effects Assessment Summary Tables*. Office of Emergency and Remedial Response. OHEA ECAO-CIN-821. Washington, D.C.
- US Geological Survey (USGS). 1989. Letter Report for Initial Site Investigation at the KC-135 Crash Site. Wurtsmith AFB, Michigan. April
- Wiedemeier, T.H., Henry, R.L., Guest, P.R., and Keith, L.B. 1993. "The Use of Bioplume to Support Regulatory Negotiations at a Fuel Site near Denver, Colorado," *Proceedings of the NWWA/API Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration*.
- Weidemeier, Todd H., Downey, Douglas C., Wilson, John T., Kampbell, Donald H., Miller, Ross N., and Hansen, Jerry E. In Progress. *Technical Protocol for Implementing the Intrinsic*

Remediation (Natural Attenuation) with Long-term Monitoring Option for Dissolved-phase Fuel Contamination in Ground Water. Prepared by the Air Force Center for Environmental Excellence.

Wurtsmith AFB. 1993. Preliminary Final Environmental Impact Statement, Disposal and Reuse of Wurtsmith Air Force Base, Michigan. June 1993.

WW Engineering & Science. 1993. Remedial Investigation Report for KC-135 Crash Site (SS-51), Wurtsmith Air Force Base, Oscoda, Michigan, 1993. Prepared for United States Department of the Air Force 379th SG/DEV, Wurtsmith AFB, Michigan 48753-5000 Project ZJXD 91-0067-1 Contract No. F20603 92 D0002/0001. Prepared by WW Engineering & Science, 5555 Glenwood Hills Parkway, Grand Rapids, Michigan 49588-0874. June 1993.

Wilson, J.T., Leach, L.E., Henson, M., and Jones, J.N. 1986. "In Situ Bioremediation as a Ground Water Remediation Technique," *Ground Water Monitoring Review* Fall, p. 56-64.

APPENDIX A
SAMPLING AND ANALYSIS PLAN

SITE SAMPLING AND ANALYSIS PLAN
FOR
RISK-BASED REMEDIATION DEMONSTRATION
AT THE KC-135 CRASH SITE
WURTSMITH AFB, MICHIGAN

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
TECHNOLOGY TRANSFER DIVISION (ESR)
BROOKS AIR FORCE BASE, TEXAS 78235-5000

USAF CONTRACT F41624-93-C-8044

November 1994

Prepared by:

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290

CONTENTS

| | <u>Page</u> |
|------------------------------------------------------------------------------------------------------|-------------|
| A.1.0 Purpose | A-1 |
| A.2.0 Drilling, Soil Sampling, and Bioventing and Ground Water Monitoring Well Installation | A-1 |
| A.2.1 Well Locations and Completion Intervals..... | A-1 |
| A.2.2 Drilling and Soil Sampling Procedures..... | A-1 |
| A.2.2.1 Pre-Drilling Activities..... | A-2 |
| A.2.2.2 Equipment Decontamination Procedures..... | A-2 |
| A.2.2.3 Drilling and Soil Sampling..... | A-3 |
| A.2.2.4 Minimization and Management of Drilling Residuals..... | A-4 |
| A.2.3 Bioventing Well Installations | A-4 |
| A.2.4 Ground Water Monitoring Well Installation..... | A-6 |
| A.2.4.1 Well Material Decontamination..... | A-6 |
| A.2.4.2 Well Casing..... | A-6 |
| A.2.4.3 Well Screen..... | A-6 |
| A.2.4.4 Sand Filter Pack and Annular Sealant | A-10 |
| A.2.4.5 Flush-Mount Protective Cover..... | A-10 |
| A.2.5 Well Development..... | A-10 |
| A.2.6 Well Development Records | A-11 |
| A.2.7 Water Level Measurements | A-11 |
| A.2.8 Borehole Abandonment..... | A-11 |
| A.2.9 Well Location and Datum Survey | A-14 |
| A.2.10 Site Restoration..... | A-14 |
| A.3 Ground Water Sampling | A-14 |
| A.3.1 Ground Water Sampling Locations..... | A-15 |
| A.3.2 Preparation for Sampling..... | A-15 |
| A.3.3 Equipment Decontamination..... | A-15 |
| A.3.4 Equipment Calibration..... | A-16 |
| A.3.5 Sampling Procedures..... | A-16 |
| A.3.5.1 Preparation of Location..... | A-16 |
| A.3.5.2 Water Level and Total Depth Measurements | A-16 |
| A.3.5.3 Well Purging | A-16 |
| A.3.5.4 Sample Extraction | A-17 |
| A.3.6 Onsite Chemical Parameter Measurement | A-17 |
| A.3.7 Sample Handling | A-17 |
| A.3.7.1 Sample Container and Labels..... | A-17 |
| A.3.7.2 Sample Preservation | A-18 |
| A.3.7.3 Sample Shipment..... | A-18 |
| A.3.7.4 Chain-of-Custody Control | A-18 |
| A.3.7.5 Sampling Records..... | A-19 |
| A.3.8 Laboratory Analyses..... | A-20 |
| A.3.9 Quality Assurance/Quality Control Samples..... | A-20 |
| A.4 Field Quality Assurance/Quality Control Samples..... | A-20 |
| A.4.1 Trip Blanks | A-21 |
| A.4.2 Decontamination Water Blanks..... | A-21 |
| A.4.3 Field Blanks | A-21 |

CONTENTS (Continued)

| | <u>Page</u> |
|---------------------------------------|-------------|
| A.4.4 Equipment Rinseate Blanks | A-21 |
| A.4.5 Field Duplicate Samples | A-21 |

FIGURES

| <u>No.</u> | <u>Title</u> | <u>Page</u> |
|------------|-----------------------------------------------------------------------|-------------|
| A.1 | Geologic Boring Log | A-5 |
| A.2 | Typical Shallow Monitoring Well Completion Diagram | A-7 |
| A.3 | Proposed Intermediate Depth Monitoring Well Construction Detail | A-8 |
| A.4 | Proposed Deep Monitoring Well Construction Detail | A-9 |
| A.5 | Well Installation Record | A-8 |
| A.6 | Well Development Record | A-9 |
| A.7 | Ground Water Sampling Record | A-12 |

A.1.0 PURPOSE

The purpose of this site-specific sampling and analysis plan (SAP) is to provide the procedures to be followed when collecting additional data in support of the risk-based approach to remediation at the KC-135 crash site. Details on analytical requirements, desired quantitation (detection) limits, and proposed sample locations are identified within section 4 of the work plan. Specific health and safety requirements are described in both the program health and safety (H&S) plan and the site-specific addendum (Appendix B). The need to collect additional samples to meet quality assurance requirements are described in the program quality assurance project plan (QAPP). Specific quality assurance sampling requirements for the KC-135 crash site are summarized herein as part of the site-specific sampling procedures. These additional samples will be used to determine the precision, accuracy, completeness, and representativeness of the final data set.

Drilling, soil sampling, lithologic logging, and bioventing and ground water monitoring well installation procedures are described in Section 2; ground water sampling procedures are described in Section 3; and field quality assurance/quality control (QA/QC) samples are described in Section 4.

A.2.0 DRILLING, SOIL SAMPLING, AND BIOVENTING AND GROUND WATER MONITORING WELL INSTALLATION

To further characterize the hydrogeologic conditions of the shallow soil and ground water for quantitative fate and transport analyses using the Bioplume II model, an estimated 13 soil borings will be drilled and 12 new wells will be installed at the KC-135 crash site. The remaining soil boring will be abandoned following soil sampling activities. The following sections describe the proposed well locations and completion intervals, equipment decontamination procedures, drilling and soil sampling, well installation, well development procedures, and well location and datum surveying. All drilling, soil sampling, and well installation will proceed from areas suspected to be least contaminated to areas suspected to be more contaminated.

A.2.1 Well Locations and Completion Intervals

Approximately 12 new wells will be installed to further characterize soil and ground water quality at the site, and support source removal activities if necessary. Ten of these wells will be screened from approximately 5 feet above to 5 feet below the ground water table. Depth to ground water in the shallow aquifer is approximately 10 feet bgs. Completion depths for the shallow wells are expected to be approximately 15 feet bgs. The remaining two wells (W-409M and W-409D) will be screened in the middle and bottom of the shallow aquifer. Additional intermediate and deep wells will be installed only if COC are detected in wells W-409M and W-409D. The new well locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model and to support source removal activities as necessary. Figure 4.1 in the body of the work plan shows the proposed well locations.

A.2.2 Drilling and Soil Sampling Procedures

This subsection addresses the procedures for drilling soil borings that will be used for soil sampling and completed as new wells. All new monitoring wells will be installed in

accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (EPA, 1987).

A.2.2.1 Pre-Drilling Activities

All necessary digging, drilling, and well installation permits will be obtained by Wurtsmith AFB personnel prior to ES mobilizing to the field. In addition, all utility lines will be located and proposed drilling locations cleared prior to any drilling activities.

A.2.2.2 Equipment Decontamination Procedures

Water to be used in drilling, equipment cleaning, or grouting will be obtained from one of the base's onsite water supplies. Wurtsmith AFB personnel will assist ES field personnel in locating a suitable source. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for the activities listed above. A decontamination water blank will be collected from the potable water source. The procedures for the collection of the decontamination water blank will be described in Section A.4. The ES field hydrogeologist will make the final determination as to the suitability of site water for these activities.

Prior to arriving at the site, and between each drilling site, the drill rig, augers, drilling rods, bits, casing, samplers, tools and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

During drilling operations, the drill rig, augers, and any down-hole drilling and/or sampling equipment will be decontaminated at a temporary decontamination pad that will be set up at each borehole location. All decontamination fluids generated at the temporary decontamination pad will be discharged on the ground surface near each borehole.

All sampling tools will be cleaned onsite, prior to use and between each sampling event, with a clean water/phosphate-free detergent mix, a clean water rinse, methanol rinse and a distilled water rinse. All well completion materials that are not factory sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the ES field hydrogeologist will not be used. All decontamination activities will be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

If contaminated soils are encountered during drilling (based on visual, olfactory, or volatile organic analyzer indications), and the potential for cross-contamination is anticipated, drilling will be stopped and modified drilling procedures will be implemented to prevent the transfer of contaminants to deeper strata.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials will not be stored near or in areas which could be affected by these substances. The drill rigs will not be allowed onsite unless they are free from leaks in any hydraulic lines, and are free of any exterior oil and grease.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled drilling fluid will not be allowed to enter any boring or well either during or after drilling/well construction.

To prevent this from happening, starter casing, recirculation tanks, berms around the borehole, and surficial bentonite packs, as appropriate, will be used.

A.2.2.3 Drilling and Soil Sampling

Drilling will be accomplished using hollow-stem augers. The borings will be drilled and sampled at selected depths to the proposed total depth of the monitoring well. A final borehole diameter of at least 10 inches (minimum auger ID of 6 inches) will be required for the installation of bioventing air injection wells with 4-inch inside-diameter (ID) casing. For installation of 2-inch-diameter ground water monitoring wells, the auger ID will not be less than 4 inches. Borings for surface casing will be drilled using 12-inch ID augers. Determination of well completion details will be at the discretion of the ES field hydrogeologist.

If subsurface conditions are such that the planned drilling technique does not produce acceptable results (e.g. unstable borehole walls or poor soil sample recovery) another technique deemed more appropriate to the type of soils present will be used. Any alternate soil sampling procedure used must be approved by the ES field hydrogeologist and will be appropriate for the subsurface lithologies present at the site.

Soil samples will be obtained using a standard split-spoon sampling device or another similar method judged acceptable by the ES field hydrogeologist. Samples will be collected in 2-foot intervals from the first 2 feet bgs, from approximately 5 to 7 feet bgs, from the capillary fringe, and the upper 4 feet of the saturated zone. Additional split spoon samples may be collected at the discretion of the ES field hydrogeologist. The ES field hydrogeologist will identify which samples from the sampling device will be submitted for chemical analysis. Soil samples which may be retained for chemical analysis will be placed in sample containers immediately after the sampler is opened. A maximum of one soil sample for chemical analysis will be collected per borehole. All soil samples will be evaluated for lithologic characteristics, however.

Every 2-foot soil sample recovered will be subsampled, composited, and placed in a clean container for PID or similar hydrocarbon vapor analyzer headspace measurements for VOCs. Representative portions of the soil samples collected for the headspace procedure will be quickly transferred to the sample containers, which will be sealed and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements will be made by puncturing the container seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The PID will be calibrated daily to 100 parts per million, volume per volume of isobutylene. It is anticipated that headspace measurements will be performed on all samples collected during the drilling operations to determine which soil samples will be submitted for chemical analysis. The PID will also be used to monitor the worker breathing zone.

As a check on the quality of field sampling activities (sampling, containerization, shipment, and handling) QA/QC trip blanks, field blanks, equipment rinseate samples, and field duplicates will be sent to the laboratory. QA/QC sampling will include a minimum of one duplicate for soil samples (i.e., frequency of 10 percent), one rinseate samples (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual cooler sent to the analytical laboratory. The procedures for the collection of field QA/QC samples are discussed below in Section A.4. Laboratory QA/QC procedures will include one matrix spike analysis,

one laboratory control sample, and one laboratory blank test for each specific analysis requested. In addition, one GC confirmation analysis for BTEX will be performed.

The ES field hydrogeologist will be responsible for observing all drilling and well installation activities, maintaining a detailed descriptive log of subsurface materials recovered, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure A.1. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Soil or rock description, including: relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations;
- Lithologic contacts: the depth of lithologic contacts and/or significant textural changes will be measured and recorded to the nearest 0.1 foot (1 inch); and
- Determination on whether soil sample will be submitted for chemical analysis or segregated as uncontaminated medium.

A.2.2.4 Minimization and Management of Drilling Residuals

Drilling activities will generate soil cuttings requiring proper handling and, if contaminated, proper disposal. Based on data from previous soil sampling efforts at the site, soil contamination does not exist above the water table and only a small portion of the drill cuttings (possibly from the saturated zone) is expected to be contaminated. Care will be taken to segregate uncontaminated soils from soils containing fuel residuals. Soils will be screened using a PID or similar hydrocarbon vapor analyzer. Clean soils will be spread on the ground surface adjacent to each soil boring. Contaminated soils will be placed in 55-gallon DOT-approved drums then placed by ES into an enclosed, above-ground, biotreatment cell located near Site OT-45.

The biotreatment cell will consist of contaminated soil placed on, and covered with plastic sheets secured with sandbags. To supply necessary oxygen, perforated plastic drain pipe, spaced horizontally approximately every 3 feet, will be placed within the contaminated soil. Oxygen will be distributed throughout the soil volume by a combination of passive ventilation and diffusion. A soaker hose will also be woven through the soil volume to supply additional moisture if necessary. A small quantity of commercial fertilizer will be mixed with the contaminated soil to provide additional nitrogen for the soil microbes.

A.2.3 Bioventing Well Installations

The potential for vadose soil contamination will be determined at 10 borings in the grassy area near the center of the KC-135 crash site. If soil sampling reveals that the fuel-contaminated interval above the ground water surface exceeds 2 feet, that boring will be completed as a combined groundwater monitoring/bioventing air injection well and later

BOREHOLE LOG

[illegible]

DRILLING CONTR.

AL

LOGGED BY:

DATE _____ CHK'D BY _____

Figure A.1
Geologic Boring Log

included in a possible full-scale bioventing system for reducing contamination in the source area. These 4-inch-diameter bioventing wells will be completed using the same design as the 2-inch diameter groundwater monitoring wells.

A.2.4 Ground Water Monitoring Well Installation

Ground water monitoring wells will be installed in 11 of the soil borings not completed as bioventing wells at the KC-135 crash site to delineate the extent of the dissolved phase plume in ground water. Additionally, one ground water monitoring well will be installed approximately 2000 feet downgradient of the KC-135 crash site to determine down-gradient hydrogeologic and chemical characteristics of the aquifer.

Detailed well installation procedures are described in the following paragraphs. Typical well completion diagrams are included as Figures A.2 through A.4.

A.2.4.1 Well Material Decontamination

Well completion materials will be inspected by the ES field hydrogeologist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned with a high-pressure, steam/hot water cleaner using approved water prior to use. Prepackaged sand, bentonite, and Portland® cement will be used in well construction, and the bags will be inspected for possible external contamination before use. Materials that cannot be cleaned to the satisfaction of the ES field hydrogeologist will not be used.

A.2.4.2 Well Casing

Upon completion of drilling to the proper boring termination depth, a monitoring well casing will be installed. Well construction details will be noted on a Monitoring Well Installation Record form, as shown in Figure A.5. This information will become part of the permanent field record for the site. Blank well casing will be constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches (4 inches for bioventing wells). All well casing sections will be flush-threaded; glued joints will not be used. The casing at each well will be fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing. The top cap will be vented to maintain ambient atmospheric pressure within the well casing. The surface casing for the intermediate and deep wells will be 8-inch diameter, Schedule 80 PVC with flush-threaded joints.

The ES field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

A.2.4.3 Well Screen

Well screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches (4 inches for bioventing wells). The screens will be factory slotted with 0.010-inch openings. Screen lengths will be 10 feet for the shallow wells, and 5 feet for the intermediate and deep wells. Each shallow well will be screened so that seasonal fluctuations of the water table can be measured. The water level in the unconfined aquifer will be allowed to fluctuate within the screened interval. The position of the screen will be selected by the ES field hydrogeologist

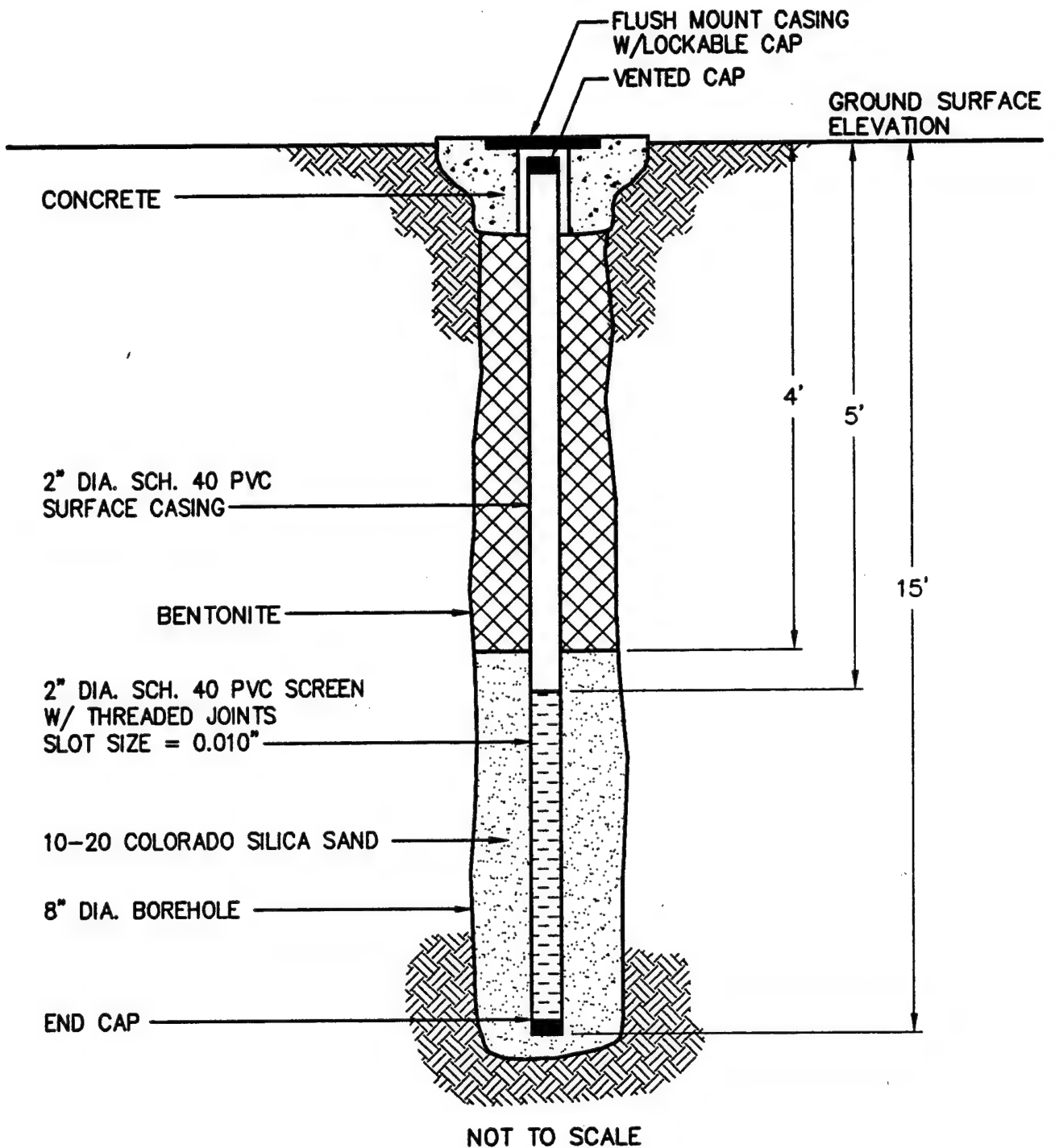


FIGURE A.4
**TYPICAL SHALLOW
MONITORING WELL
COMPLETION DIAGRAM**

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site,
Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado

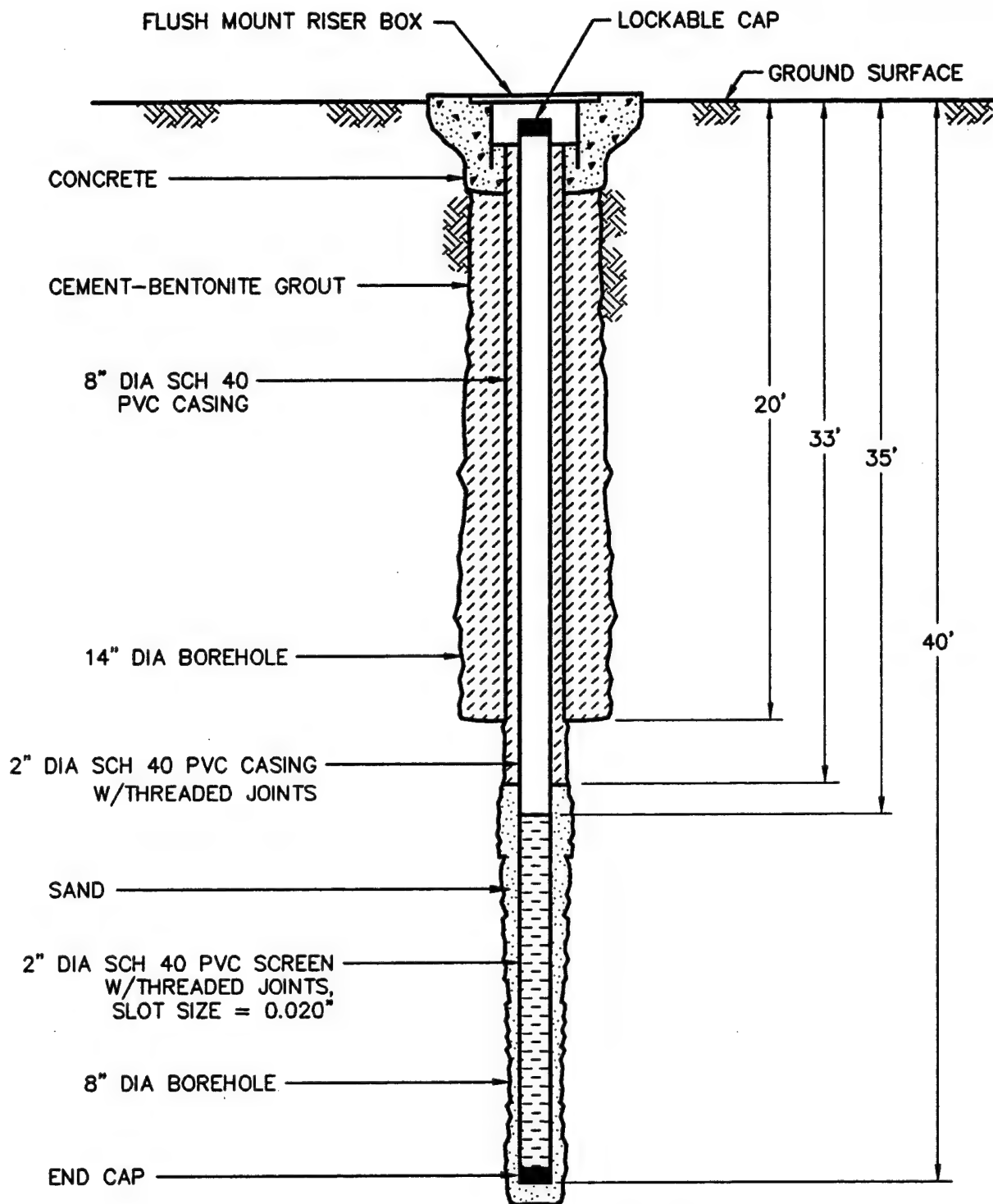


FIGURE A.3

**PROPOSED INTERMEDIATE DEPTH
MONITORING WELL
CONSTRUCTION DETAIL**

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site,
Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado

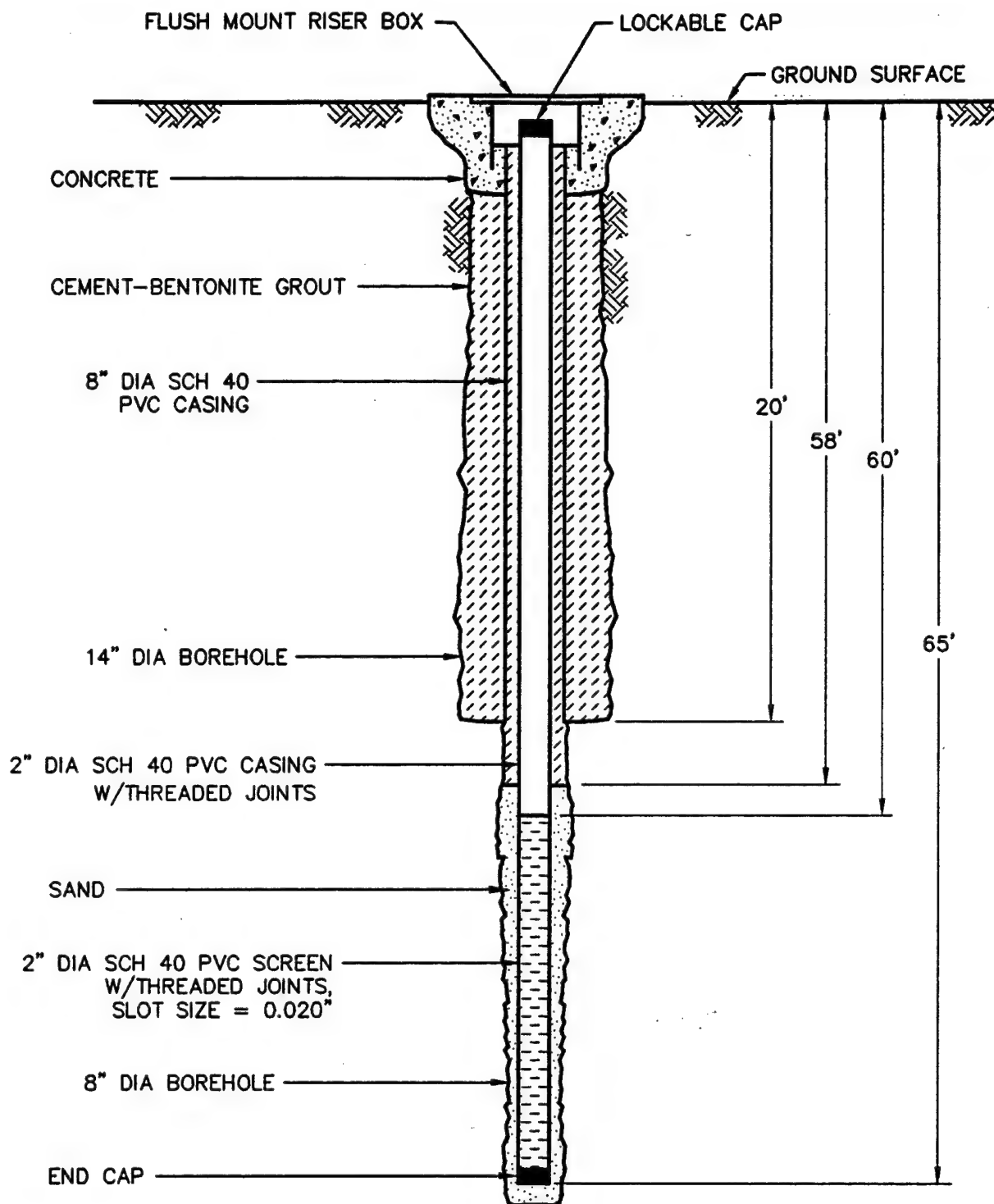


FIGURE A.4

**PROPOSED DEEP MONITORING
WELL CONSTRUCTION DETAIL**

RAP Work Plan
Risk-Based Approach to Remediation
KC-135 Crash Site,
Wurtsmith AFB, Michigan

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Well No. _____
 Boring No. X-Ref: _____

MONITORING/SAMPLING POINT CONSTRUCTION SUMMARY

Survey Coords: _____ Elevation Ground Level _____
 _____ Top of Casing _____

Drilling Summary:

Total Depth _____
 Borehole Diameter _____
 Casing Stick-up Height: _____
 Driller _____

 Rig _____
 Bit(s) _____

 Drilling Fluid _____

 Protective Casing _____

Construction Time Log:

| Task | Start | | Finish | |
|-------------------|-------|------|--------|------|
| | Date | Time | Date | Time |
| Drilling | | | | |
| | | | | |
| | | | | |
| Geophys. Logging: | | | | |
| Casing: | | | | |
| | | | | |
| | | | | |
| Filter Placement: | | | | |
| Cementing: | | | | |
| Development: | | | | |
| | | | | |
| | | | | |

Well Design & Specifications

Basis: Geologic Log _____ Geophysical Log _____
 Casing String (s): C = Casing S = Screen.

| Depth | String(s) | Elevation |
|-------|-----------|-----------|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

Casing: C1 _____

C2 _____

Screen: S1 _____

S2 _____

Filter Pack: _____

Grout Seal: _____

Bentonite Seal: _____

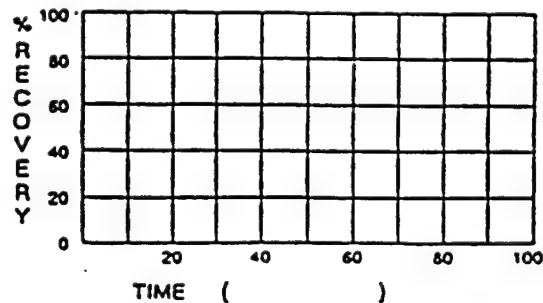
Well Development:

Stabilization Test Data:

| Time | p H | Spec. Cond. | Temp (C) |
|-------|-------|-------------|------------|
| _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ |

Recovery Data:

Q = _____ S₀ = _____



Comments: _____

Figure A.5
 Well Installation Record

SITE NAME _____

SUPERVISED BY _____

after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

A.2.4.4 Sand Filter Pack and Annular Sealant

A graded sand filter will be placed around the screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand. An annular seal will be placed above the sand pack using sodium bentonite chips. The bentonite seal will be a minimum of 3 feet thick and will be hydrated in place with potable water. The bentonite seal will extend to the base of the protective well cover.

A.2.4.5 Flush-Mount Protective Cover

Each monitoring well will be completed with an at-grade (flush-mount) protective cover. A 6-inch thick, 2-foot-diameter concrete pad will be constructed around the protective cover. The concrete pad surrounding the well cover will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

A.2.5 Well Development

Before any new well can be considered in proper condition for monitoring water levels or taking water samples, it must be developed. Development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen. Well development will occur no sooner than 48 hours after sealing of the annulus is completed.

Well development will be accomplished using dedicated disposable bailers or decontaminated Teflon® bailers to surge the well, and pump to remove the water and sediment. The bailer or pump will be lowered to the bottom of the well so that fines which have accumulated in the bottom are agitated and removed from the well in the development water.

Development will be continued until a minimum of three casing volumes of water have been removed from the well and the water pH, temperature, and specific conductivity have stabilized. Temperature, pH and specific conductivity will be monitored during development (one reading for each parameter per well volume). Pumping will continue until these parameters have stabilized to within 10 percent among three consecutive readings and the water is clear and free of fines. The pH and specific conductivity meters will be calibrated on a daily basis. The pH meter will be calibrated by laboratory-prepared standard solutions following the manufacturer's calibration procedures. The specific conductivity meter will be calibrated using laboratory-prepared known conductivity solutions. If the development water still is turbid after removal of three casing volumes, development will be continued until the water becomes clear or the turbidity of the water produced has been stable after the removal of several casing volumes.

The development procedure specifies that three casing volumes of water be removed from the well. However, some wells completed in marginal aquifers will go dry during well development prior to the recovery of three casing volumes. In these low-productivity wells, development activity may have to be staged over a period of time to allow water to refill the

well bore. In the event three casing volumes of water cannot be recovered, the water volume recovered will be noted in the development records.

All well purge water will be temporarily placed in 55-gallon D.O.T. approved containers. Final disposal will be determined based on laboratory analytical results. Water with COC concentrations below Michigan Type B levels will be discharged onto the ground surface near the source well. Water with contamination above hte Type B levels will trtansported and discharged to either the Wurtsmith AFB or Oscoda Township waste water treatment plants, depending on contaminant concentrations.

A.2.6 Well Development Records

A record of well development will be maintained for each well. The well development record will be maintained in a bound field notebook by the field hydrogeologist. Figure A.6 is an example of the well development record. A summary well development record form will be prepared for each well and submitted with the RAP report. Development records will include:

- Well number;
- Date and time of development;
- Development method;
- Predevelopment water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and well depth; and
- Field analytical measurements, including pH and specific conductivity.

A.2.7 Water Level Measurements

Water levels at all wells will be measured within a short time interval so that the water-level data are comparable. Water levels in the new wells will not be measured until they are developed and the water level has stabilized. The depth to water below the measurement datum will be made using an oil/water interface electric probe to the nearest 1/8 inch (0.01 foot). The oil/water interface probe will be decontaminated prior to use, and between each measurement, following the decontamination procedures presented in Section A.3.3. In addition, water level measurements will be made in all existing ground water monitoring wells at the site. This data will be used to calibrate the Bioplume II model and describe hydrogeologic characteristics.

A.2.8 Borehole Abandonment

Portland® cement/sodium bentonite grout will be used to abandon any soilboring not completed as a monitoring well. The grout will extend from total depth to the ground surface. The Portland® cement/sodium bentonite grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite will not exceed 8 percent by dry weight

Figure A.6
Well Development Record

Page__ of __

Job Number _____
Location _____
Well Number _____

Job Name _____
By _____ Date _____
Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature (°F °C) _____
Specific Conductance (μS/cm) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°F °C) _____

Specific Conductance (μS/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature (°F °C) _____
Specific Conductance (μS/cm) _____

Comments: _____

A.2.9 Well Location and Datum Survey

The location and elevation of the new wells will be surveyed by a registered surveyor soon after well completion. Horizontal locations will be measured relative to established Wurtsmith AFB coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the well casing, the measurement datum (top of the interior casing), and the top of the outer well casing will be measured relative to a USGS MSL datum. The ground surface elevation will be measured to the nearest 0.1 foot, and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

A.2.10 Site Restoration

After well installation and sampling is complete, each well site will be restored as closely to its original condition as possible.

A.3.0 GROUND WATER SAMPLING

This section describes the scope of work required for collecting ground water samples at each of the 12 new wells and 8 existing ground water monitoring wells. All water samples collected from ground water monitoring wells will be obtained using either disposable bailers, decontaminated Teflon[®] bailers, or a thoroughly decontaminated peristaltic pump. In order to maintain a high degree of quality control during this sampling event, the procedures described in the following sections will be followed.

Ground water sampling will be conducted by qualified ES scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed the work plan and this site-specific sampling and analysis plan prior to sample acquisition and will have a copy of both available onsite for reference.

Activities that will occur during ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including:
 - Protective cover, cap and lock,
 - External surface seal and pad,
 - Well stick-up, cap, and datum reference,
 - Internal surface seal,
 - Condition of bladder pump if present;
- Ground water sampling, including:
 - Water-level measurements,
 - Visual inspection of borehole water,
 - Well casing evacuation,

- Sampling;
- Sample preservation and shipment, including:
 - Sample preparation,
 - Onsite measurement of physical parameters,
 - Sample labeling;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

A.3.1 Ground Water Sampling Locations

Ground water samples will be collected from 12 newly installed wells (W-407 through W-416) and 8 existing wells (W-400 through W-406, and USGS4) using either a disposable bailer or a thoroughly decontaminated peristaltic pump.

A.3.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all recordkeeping materials will be gathered prior to leaving the office.

A.3.3 Equipment Decontamination

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This equipment includes the Teflon[®] bailers, water-level probe and cable, dissolved oxygen probe and cable, test equipment for onsite use, and other equipment or portions thereof which will contact the samples. Based on the types of sample analyses to be conducted, the following decontamination protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent;
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol; and
- Air dry the equipment prior to use.

All decontamination fluids will be contained in 55-gallon drums and disposed of as described in Section A.1.5. Any deviations from these procedures will be documented in the field scientist's field notebook and on the ground water sampling form. If pre-cleaned dedicated sampling equipment is used, the decontamination protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field.

A.3.4 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as pH, electrical conductivity, and temperature.

A.3.5 Sampling Procedures

Special care will be taken to prevent contamination of the ground water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient decontamination of equipment between wells. To prevent such contamination, the water level probe and cable used to determine static water levels and well total depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section A.3.3. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time a different well is sampled. . New, clean tubing will be used for the peristaltic pump for each well. Wells will be sampled sequentially from areas suspected to be least contaminated to areas suspected to be more contaminated.

The following paragraphs present the procedures that comprise ground water sample acquisition from all ground water sampling locations. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the ES field scientist's field notebook.

A.3.5.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well.

A.3.5.2 Water Level and Total Depth Measurements

Prior to removing any water from the well the static water level will be measured. An electrical water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the well and the total well depth will be measured to the nearest 0.01 foot. Based on these measurements the volume of water to be purged from the well can be calculated.

Emphasis will also be placed on defining the probable areal extent of any remaining free fuel product that may act as a continuing source of contamination at the site. Free product can be physically identified during drilling and soil sampling and through the use of an oil/water interface probe.

A.3.5.3 Well Purging

The volume of water contained within the well casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well. The pH, temperature, dissolved oxygen, and specific conductivity will be monitored during well

purging. Purging will continue until these parameters have stabilized to within 10 percent among three consecutive readings. All purge water will be placed in 55-gallon drums and disposed of as described in Section A.2.5. Teflon® bailers or a peristaltic pump will be used for well evacuation.

If a well is evacuated to a dry state during purging, the well will be allowed to recharge to 80 percent of its original water level and the sample will be collected as soon as sufficient water is present in the well to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to eventually obtain a sample of sufficient volume, will not be allowed.

A.3.5.4 Sample Extraction

A peristaltic pump will be used to extract ground water samples from the well. The extraction equipment will be lowered into the water gently to prevent splashing and extracted gently to prevent creation of an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for well purge waters disposed of as described in Section A.2.5.

A.3.6 Onsite Chemical Parameter Measurement

Dissolved oxygen (DO) measurements will be taken onsite using a meter with a downhole oxygen sensor. The DO meter will be decontaminated, prior to each use, following decontamination procedures described in Section A.3.3. DO measurements will be taken immediately preceding ground water sample acquisition. Where DO measurements will be taken in wells which have not been sampled, the well will be purged as described earlier prior to taking the DO measurement.

Because the pH, temperature, specific conductance, redox potential, and other chemical parameters of a ground water sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean, plastic, flow-through cell and the measured values will be recorded in the ground water sampling record. Table 4.1 in the body of the work plan lists the chemical analytical protocol for ground water samples.

A.3.7 Sample Handling

This section describes the handling of samples from the time of sampling until the samples arrive at the laboratory.

A.3.7.1 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the laboratory. The sample containers will be filled as described in Section A.3.5.4, and the container lids will be

tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (ground water, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

A.3.7.2 Sample Preservation

The laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of approximately 4 degrees centigrade (°C).

A.3.7.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to Evergreen Analytical, Inc. of Wheat Ridge, Colorado, the AFCEE-approved laboratory for this demonstration. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
 - Sample collector's name, address, and telephone number;
 - Laboratory's name, address, and telephone number;
 - Description of sample;
 - Quantity of sample; and
 - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition.

A.3.7.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling contractor after sample delivery to the analytical laboratory, and the other two copies will be retained at the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

A.3.7.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the ES field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance,
 - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and

- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure A.7 shows an example of the ground water sampling record.

A.3.8 Laboratory Analyses

Laboratory analyses will be performed on all ground water samples and the required QA/QC samples (see section A.3.9). The analytical methods and detection limit requirements for this sampling event are listed in Table 4.1 in the body of the work plan. Evergreen Analytical Laboratories of Golden, Colorado will be performing the laboratory analytical analysis.

Prior to sampling, arrangements will be made with the laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with laboratory protocol.

Laboratory personnel will specify any additional QC samples and prepare bottles for all samples. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratories.

A.3.9 Quality Assurance/Quality Control Samples

Field QA/QC procedures for ground water will include collection of field duplicates and rinseate, field and trip blanks, decontamination of the water level probe, use of analyte-appropriate containers, and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., ground water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Ground water QA/QC sampling will include duplicates for up to two wells (i.e., frequency of 10 percent), rinseate blanks for up to two wells (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual cooler sent to the analytical laboratory. The procedures for the collection of field QA/QC samples are described in Section A.4. The laboratory should plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

A.4.0 FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on field sampling, QA/QC samples, including trip blanks, field blanks, decontamination water blanks, equipment rinseate blanks, and field duplicates will be collected. Each type of QA/QC sample is described below.

Figure A.7
Ground Water Sampling Record

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.
SAMPLE COLLECTED BY: _____ of _____
WEATHER: _____
DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED: ☐ UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT _____
STEEL CASING CONDITION IS: _____
INNER PVC CASING CONDITION IS: _____
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT _____
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

- 1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____

- 2 ☐ WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____
- 3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____
- 4 ☐ WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: _____ ° _____ Measured with: _____
pH: _____ Measured with: _____
Conductivity: _____ Measured with: _____
Other: _____

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

[] Preservatives added:
Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
[] Container Lids Taped
[] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

A.4.1 Trip Blanks

A trip blank is defined as a sample bottle filled by the laboratory with analyte-free laboratory reagent-grade water, transported to the site, handled like a sample but not opened, and returned to the laboratory for analysis. One trip blank will accompany every cooler of environmental samples sent to the laboratory. Trip blanks are analyzed only for Method SW8020.

A.4.2 Decontamination Water Blank

A decontamination water blank is designed to check the purity of potable water used for equipment decontamination during the field operation. One decontamination water blank will be collected for each water source used during the field work. Decontamination water blanks are collected by filling the appropriate sample container directly from the potable water source. Decontamination water blanks are labeled, preserved, handled, and shipped in the same manner as an environmental water sample. The blank will be analyzed for the same analytes and parameters as the environmental samples.

A.4.3 Field Blanks

A field blank is designed to assess the effects of ambient field conditions on sample results. A field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for the same analytes and parameters as the environmental samples.

A.4.4 Equipment Rinseate Blanks

Equipment rinseate blanks will be collected from field equipment such as the split spoon sampling device. Equipment rinseate blanks are prepared by pouring distilled water over field equipment that has been decontaminated. The rinseate water is then collected, transferred to a sample bottle, and analyzed at the laboratory. The results of these sample analyses indicate how well the sampling equipment was decontaminated.

A.4.5 Field Duplicate Samples

A field duplicate is defined as two or more samples collected independently at the same sampling location during a single act of sampling. Soil samples are divided into two equal parts for analysis. Duplicates of water samples will be collected by filling additional sample containers at each duplicated sampling event.

Field duplicates will be indistinguishable from other samples by the laboratory. One complete sample set will be identified with a coded identifier, which will be in the same format as other identifiers used with this matrix. Both the coded and actual sample identifiers will be recorded in the field notebook. The coded identifier will be used on the chain-of-custody forms. A more comprehensive discussion of QA/QC requirements is presented in the Quality Assurance Project Plan (ES, 1994).

APPENDIX B
HEALTH AND SAFETY PLAN

ADDENDUM TO THE PROGRAM HEALTH AND SAFETY PLAN
FOR THE RISK BASED DEMONSTRATION AT SITE OT45

BASE NAME: WURTSMITH AFB

JOB #725523.02000

Installation Manager

John Hall

Site Health and Safety Officer:

Nick Marcelletti

Site Contact:

**Bruce Bolan
Paul Rekowski
(517) 739-9793**

REVIEWED AND APPROVED BY:

Project Manager _____
Name Date

**Program H&S
Manager:** _____
Name Date

1.0 INTRODUCTION

This addendum modifies the existing *Program Health and Safety Plan for Risk-Based Remediation Demonstrations* (Engineering-Science, Inc., 1994), for conducting progressive site investigations at United States Air Force facilities under contract number F41624-93-C-8044.

This addendum outlines the site-specific requirements and provides site-specific information for work to be conducted at Wurtsmith AFB, Michigan. The site to be investigated through a risk-based remediation approach will be the KC-135 Crash Site.

The demonstration to be conducted at the KC-135 Crash Site of an innovative technology is sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, Texas under Contract F41624-93-C-8004, "Risk-Based Approach to Fuel Spill Remediation."

Included or referenced in this addendum are site-specific descriptions, history and proposed field activities; hazard evaluation of known or suspected chemicals; personal protective equipment (PPE); personnel decontamination procedures; site-specific training and medical monitoring requirements; air monitoring; site control procedures; employee exposure monitoring; and emergency response procedures.

Site hazards will be assessed and communicated to the field team members to determine if hazards are present, or are likely to be present, which may necessitate the use of PPE. All ES field team members will be properly trained in the use, care, disposal, limitations, and maintenance of personal protective equipment (PPE).

2.0 SITE DESCRIPTION, HISTORY, AND SITE-SPECIFIC ACTIVITIES

The site description, history, and pilot test activities to be performed at this site are outlined in the site-specific work plan entitled *Work Plan for a Remedial Action Plan in Support of the Risk-Based Approach to Remediation at KC-135 Crash Site at Wurtsmith Air Force Base, Osoda, Michigan*. A brief listing of planned site-specific activities follows.

Services to be performed by ES include sampling of soil, soil gas, ground water, and surficial soils. In addition, a total of nineteen ground water monitoring wells, bioventing wells, or soil gas monitoring points will be installed during site investigation activities.

A sufficient number of samples from background and contaminated areas will be collected and analyzed for individual and indicator compounds to accurately assess the risk to human health and the environment posed by the site and to demonstrate the attainment of final cleanup levels.

3.0 SITE-SPECIFIC EMPLOYEE TRAINING AND MEDICAL MONITORING REQUIREMENTS

See Section 4 of the program health and safety plan (Engineering-Science, Inc., 1994) for guidance.

4.0 HAZARD EVALUATION

4.1 Chemical Hazards

General hazards are addressed in the program health and safety plan. Site-specific hazards are identified below.

Chemicals known or suspected to occur at the KC-135 Crash Site include the petroleum hydrocarbon fuel components benzene, toluene, ethylbenzene, and xylenes (BTEX) resulting from a 1,000-gallon heating oil tank.

Health hazard qualities for these compounds are presented in Table 5.1 of the program health and safety plan.

4.2 Physical Hazards

Potential physical hazards at this site include risks associated with soil intrusive activities such as underground utilities; overhead utilities; drilling activities; electrical equipment; heavy equipment; motor vehicles; slip, trip, and fall hazards; noise; and heat stress.

Protection standards for physical hazards are contained in Section 7 of the program health and safety plan.

5.0 AIR MONITORING

During operations that disturb site soils, a hydrocarbon detector or photoionization detector (PID or equivalent) will be used to measure ambient air concentrations in the worker breathing zone. As shown in the attachment, if the hydrocarbon detector measures total fuel vapor concentrations of 0-5 ppm, site workers will continue air monitoring in a Level D ensemble. If total fuel vapor concentrations reach 5-25 ppm for more than 30 seconds, and benzene concentrations exceed 1 ppm, site workers will evacuate the site or upgrade to Level B ensemble, if trained to do so. If benzene concentrations are less than 1 ppm, the site crews may continue in Level D ensemble with periodic air monitoring. If total fuel vapor concentrations reach 25-50 ppm for greater than 30 seconds and benzene concentrations exceed 1 ppm, site crews will evacuate the site or upgrade to Level B ensemble. If benzene concentrations are less than 1 ppm and vapors are in the range of 25-50 ppm, site workers will don full facepiece air-purifying respirators (APR) equipped with organic vapor cartridges (NIOSH approved), and continue periodic air monitoring. If total fuel vapor concentrations reach 50-500 ppm for greater than 30 seconds, the site crews will evacuate the site or upgrade to Level B ensemble. If total fuel vapor concentrations exceed 500 ppm for greater than 30 seconds, site crews will evacuate the site.

Before work can be performed in Level B respiratory protection the project manager must be notified. He will initiate the change order process with the Air Force or decide to halt activities at that site. (Level B operations require approval from corporate health and safety.) The site health and safety officer will determine whether it is safe to continue activities without respiratory protection or assign an upgrade to Level C protection. Flammable vapor monitoring will be conducted if potentially flammable atmospheres occur. See Sections 8 and 11 of the program health and safety plan for specific guidance.

6.0 SITE CONTROL PROCEDURES

Site control measures will be followed in order to minimize potential contamination of workers, protect the public from potential site hazards, and control access to the sites. Site control involves the physical arrangement and control of the operation zones and the methods for removing contaminants from workers and equipment. See Section 9 of the program health and safety plan for guidance.

Specific site control procedures at this site will include establishment of site work zones whenever employees are wearing respiratory protection. Unauthorized personnel will be restricted from entering the immediate work area.

7.0 PERSONAL PROTECTIVE EQUIPMENT

It is anticipated that Level D respiratory protection, with a contingency provision for the use of Level C will be used at these sites. Additional guidelines for the selection of respiratory protection at these sites are contingent upon the discovery of benzene vapors in the worker breathing zone while performing site activities. Site crews will assess the need for respiratory protection, or PPE, as applicable.

Protective clothing to be used at these sites includes:

- Hard hats
- Safety glasses
- Suits (Tyvek® or Saranex®)
- Respirator, if needed (APR with combination organic vapor/HEPA cartridges)
- Inner gloves (Latex or Vinyl)
- Outer gloves (Nitrile or Neoprene)
- Boots (Safety boots with latex boot covers)
- Other

8.0 PERSONNEL DECONTAMINATION PROCEDURES

See Section 10 of the program health and safety plan for general procedures and guidance. Of the compounds being used for decontamination, methanol is considered potentially hazardous. Methanol is volatile and flammable. The PEL for methanol is 200 ppm. An STEL of 250 ppm for 15 minutes is allowed for methanol. Exposure of the skin to methanol can result in skin burns and/or skin absorption.

The PEL for methanol can be reached when the PID is reading 8 ppm. This is because the relative response factor of methanol is 0.04 when the PID is equipped with a standard 10.2 or 10.6 eV lamp and is calibrated with 100 ppm isobutylene. Therefore, air monitoring should be performed when decontaminating equipment with methanol. If a respirator is needed during such operations, appropriate cartridges should be used. Nitrile gloves and chemical goggles should be used.

Methanol will be in plastic bottle jackets during use in the field. These bottle jackets will be properly labeled, and during transport into the field will be cushioned inside a

larger locked-lid plastic carrying container that is secured in the vehicle. All chemical wastes (waste methanol) generated during decontamination will be collected in an empty manufacturer's chemical bottle with a bottle jacket, labeled with contents, dated, and transported as described above. Call the point-of-contact at the Air Force Base for proper disposal procedures and transport to the hazardous materials storage area.

9.0 EMPLOYEE EXPOSURE MONITORING

Employee exposure monitoring will be conducted on this site in accordance with Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910) and the program health and safety plan.

10.0 EMERGENCY RESPONSE PLAN

10.1 Safe Distances and Places of Refuge

Prior to initiation of field activities, the field crew shall decide on safe distances to retreat to and select a place of refuge in the event of an emergency. This information shall be provided to all pilot test field personnel during weekly or daily site-specific safety briefings. All other guidelines established in the program health and safety plan for emergency planning, training, recognition, etc. shall be followed.

10.2 Emergency Information

Listed below are the name and phone numbers for medical and emergency services for this project.

| | |
|-----------------|-------------------------|
| Hospital | Tawas St. Joseph |
| Address | 200 Hemlock, Tawas City |
| Phone | (517) 362-3411 |

Description of the route to the hospital:

Proceed to main gate, turn right (east) on road F41 and proceed approximately 3 miles to the intersection of Highway 23. Turn right (south) on Highway 23 and proceed approximately 10 miles to Tawas City. The hospital is located at the corner of Highways 23 and 55.

Other Emergency Numbers:

| | |
|-----------------|----------------|
| Fire Department | (517) 739-9793 |
| Nearest Phone | (517) 739-1717 |
| Ambulance | (517) 362-6164 |
| Site Emergency | (517) 739-9793 |

Program Health and Safety Manager:

Tim Mustard work: (303) 831-8100
home: (303) 450-9778

Project Manager:

Doug Downey work: (303) 831-8100
home: (303) 670-0512

11.0 REFERENCES

Engineering-Science, Inc. 1994. *Work Plan for a Remedial Action Plan In Support of Risk-Based Approach to Remediation at Site OT45, Wurtsmith Air Force Base, Oscoda, Michigan.*

Engineering-Science, Inc. 1994. *Program Health and Safety Plan for Risk-Based Remediation Demonstrations.* Denver, Colorado.